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Perceived value innovation model for commercial fresh-cut fruits

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Declaration of Originality

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List of Abbreviations

AN	Air and non-perforated lidding film treatment; with post-cut sanitation wash
ANL	Same as AN but with non-visible mint leaves
ANVL	Same as AN but with visible mint leaves
AnT	Air and non-perforated lidding film treatment; no post-cut sanitation wash
AnTVL	Same as AnT but with visible mint leaves
AP	Air and perforated lidding film (larger perforations = 6 x 150 µm holes)
Ap	Air and perforated lidding film (smaller perforations = 6 x 75 µm holes)
ARC IHP	Australian Research Council Training Centre for Innovative Horticultural Products
C_M_POD	Cup, with mint, with POD packaging
C_M_UBD	Cup, with mint, without POD packaging
C_P_POD	Cup, without mint, with POD packaging
C_P_UBD	Cup, without mint, without POD packaging
CSIRO	Commonwealth Science and Industrial Research Organisation
DCE	Discrete choice experiment
E	Entgegen (German translation for "trans" isomers in the chemical structure of volatile compounds)
EO	Essential oils
FCF(s)	Fresh-cut fruit(s)
FCP(s)	Fresh-cut products
FCW	Fresh-cut watermelon
FCV(s)	Fresh-cut vegetable(s)
GC-MS-O	Gas chromatography and mass spectrometry - olfactometry
IC(s)	Innovation cycle(s)
MAP	Modified atmosphere packaging
MN	Modified atmosphere and non-perforated lidding film (smaller perforations)
MP	Modified atmosphere and perforated lidding film (larger perforations)
Mp	Modified atmosphere and perforated lidding film (smaller perforations)
OAC	Odour active compounds
PFA	Perfection Fresh Australia Pty Ltd
PLC	Product life cycle
POD	Packed on date
PTR-MS	Proton transfer reaction - mass spectrometry
PV	Perceived value
PVI	Perceived value innovation model
S_M_POD	Square, with mint, with POD packaging
S_M_UBD	Square, with mint, without POD packaging
S_P_POD	Square, without mint, with POD packaging
S_P_UBD	Square, without mint, without POD packaging
SPME GC-MS	Solid phase microextraction gas chromatography and mass spectrometry
SSC	Soluble solids content
SRQ	Subsequent research question
TA	Titratable acidity
TSS	Total soluble solids
UBD	Use-by date
VOC	Volatile organic compounds
Z	Zusammen (German translation for "cis" isomers in the chemical structure of volatile compounds)

Abstract

The market for fresh-cut fruits (FCFs) has grown in the last 40 years due to increasing demand for products characterised with high levels of convenience, nutrient value, safety and natural taste. The commercial success of FCFs, however, is still limited because of the varied consumer value perceptions and product perishability. Market innovation has previously focused on market trends and consumer behaviour to conceptualise new FCFs while technical innovations have focused on extending product shelf-life. This research was to improve the success of new FCFs by developing and testing an innovation model that integrates both market and technical innovations. The research has determined the factors that most influence perceived value (PV) of consumers for FCFs and utilised these factors as the focus of innovation. PV in this context, refers to the consumers' assessment of the expected product benefits against its projected costs. The Perceived Value Innovation (PVI) model was used to direct the innovation of fresh-cut watermelon (FCW). FCW was the focus of the innovation because it is highly perishable (~6 d shelf-life), which has negative implications for the quality perceptions of consumers.

The PVI model was implemented by first examining the consumer value perceptions and FCF cues (i.e. intrinsic such as colour and flavour, extrinsic such as packaging and label information) through intercept-administered in-store surveys using the best-worst scale method to identify the determinants and deterrents to product choice. Additionally, mini-group and individual in-depth interviews were performed using the laddering technique to understand purchase motivations and identify FCW cues utilised during purchase. Results revealed that product "freshness" and packaging elements such as packaging shape and shelf-life information were the significant product cues and drivers of purchase. Expert interviews and literature searching were then done to improve postharvest processing and packaging techniques using the concepts of "freshness" and "naturalness".

The consumer information was utilised to guide and implement the technical innovation through a series of innovation cycles (ICs) in order to develop FCW prototypes. The effects of modifying atmospheric packaging conditions (1st IC) were tested to determine the best conditions for maintaining the fresh quality of cubes. The inclusion of mint

leaves (2nd IC) and the effects of post-cut sanitation spray (3rd IC) on freshness, natural image and taste of FCW were also investigated. The three ICs focused on achieving prototypes with the highest overall acceptability scores at the end of the 8-d shelf-life, using a 9-point hedonic scale. Each IC was performed using small-scale consumer panel assessments. Subjective evaluations were then linked to objective instrumental measurements of sensory quality in order to gain meaningful information on how sensory factors contribute to consumer response. Both tests were performed simultaneously after storage for one, six and eight days at each of the three ICs. Investigations were focused on the overall flavour quality, as it deteriorates faster than appearance quality, and is, hence, an appropriate indicator of fruit "freshness". Storage odour and flavour quality were determined objectively by first identifying the odour-active compounds (OACs) released in the packaging headspace using the gas chromatography-mass spectrometry-olfactometry (GC-MS-O). Identification of OAC was confirmed using headspace solid phase microextraction gas chromatography-mass spectrometry (SPME GC-MS). Identified OAC were screened as chemical markers of "freshness" by correlation to the sensory scores for each treatment. The principal component analysis determined specific compounds (e.g. *(E,Z)*-3,6-nonadienol and *(Z)*-3-nonen-1-ol) that positively associated with perceived "freshness" and other compounds (e.g. dimethyl trisulfide and *(E,E)*-2,4-heptadienal) that were associated with negative perceptions of "freshness". Rapid monitoring of changes in the concentration of chemical markers was also measured using proton transfer reaction-mass spectrometry (PTR-MS). Volatile profile changes were attributed to the process, packaging and storage variables such as time and temperature. They were tested at each IC and were utilised for improvement of the FCW prototype. Improved prototypes were identified as single washed fresh-cut watermelon cubes (with and without mint leaves), packed under atmospheric and non-perforated film packaging condition.

Confirmation of increased perceived value for FCW was obtained through in-store purchase and consumption simulations using discrete choice consumer experiment (DCE) and informed consumer testing, respectively. Packaging designs consisting of varying container shapes (cup and square) and shelf-life information (with and without packed-on date, in addition to use-by date), were integrated into the improved FCW prototypes resulting in a total of eight actual FCW formats tested. The PV of current and potential users for these prototypes was investigated at product purchase,

consumption and repeat purchase intent stages. Research findings indicated a three-fold improvement of PV when packed on date (POD) information was on the label in addition to the mandatory use by date (UBD) information. It served as a cue to assess freshness and increase confidence in product quality and safety during purchase and has positively influenced the perceived freshness during consumption. POD was also a significant factor influencing repeat purchase intent. In the absence of POD, mint leaves served as a visual stimulus for freshness evaluation, and its combination with watermelon was highly acceptable (75 % of participants). Variations in packaging shape, however, showed insufficient evidence of PV deviation from purchase to consumption. Cup was preferred over square packaging during purchase due to volume perception, even when equal weights were indicated on the label. In contrast, square packaging received positive feedback during consumer testing because of more visible intact cubes.

The PVI model for FCF innovation therefore was able to improve the PV of FCW and provide evidence of the model's usefulness to deliver consumer-effective FCFs. The model, however, currently lacks consideration of the actual innovation and production costs. Nonetheless, the application of the model can be useful to develop leading-edge food products in comparison to competitor offerings.

Keywords: consumers, DCE, fresh-cut, GC-MS-O, Perceived Value Innovation model, PTR-MS, sensory shelf-life, SPME GC-MS

Chapter 1 Introduction

Chapter 1 introduces the thesis on the Perceived Value Innovation (PVI) model for the commercial production of fresh-cut fruits (FCFs). The research drivers (Fig. 1.1) were defined by industry collaborators as a need to improve the current empirical sales-based FCF product development approach. Variants of the consumer FCFs are made following new product development discussions and tested by supermarket sales. This leads to the need to improve the efficiency of the new product development process and the conception of the framework around the PVI model.

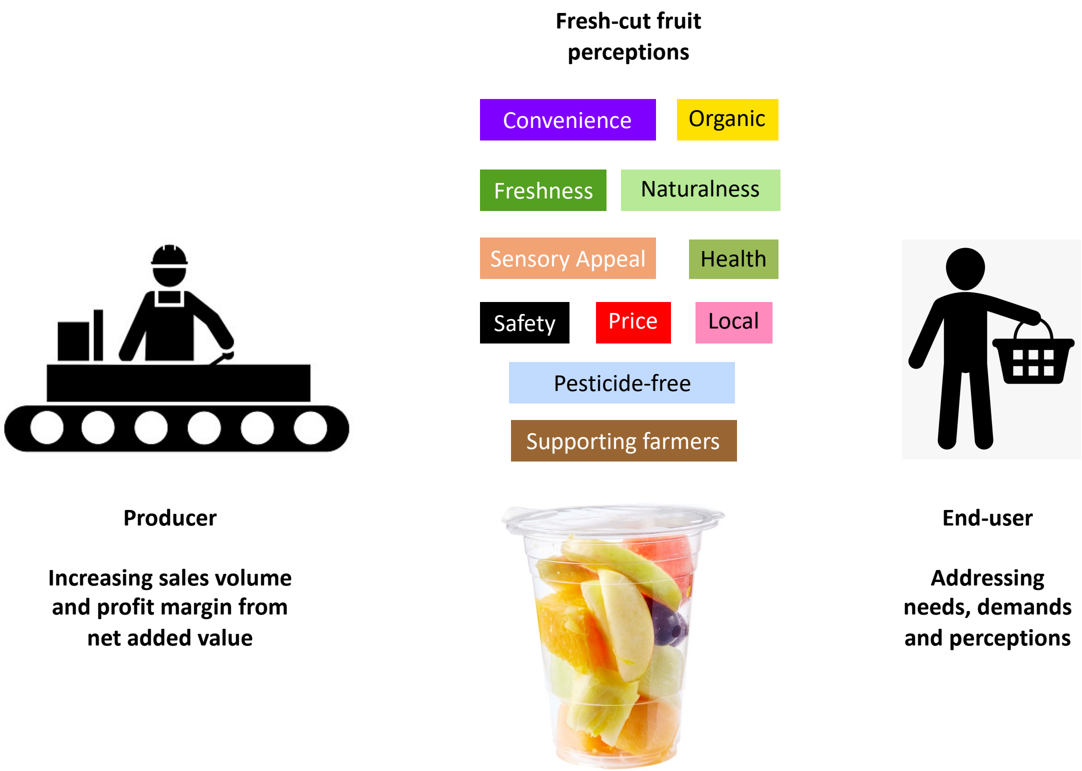

Fig. 1.1. Research drivers for improving FCF innovation.

1.1 Background to the Thesis

This thesis is a set of integrated research studies towards improving products for the FCF industry. The research studies were conducted as part of the training at the Australian Research Council Training Centre for Innovative Horticultural Products (ARC IHP)[1]. The research thrust of the training centre was to deliver industrial transformations in the fresh product supply chains through collaborations of the University with its industry partners and the government. The research was concentrated on addressing supply chain issues related to the quality and the consumer acceptance of fresh produce when it reaches the supermarket. The specific supply chains were nominated by the industry collaborators.

For this thesis, a company involved in the commercial production of FCFs for supermarket sales was the industry collaborator in order to address the quality and consumer acceptance of their products. The nominated industry currently supplies FCFs to the retail markets of large cities in Australia such as Sydney, Melbourne, Queensland and Adelaide. The research was focused on understanding the demands of the current and potential end-users of FCFs and matching innovation efforts to suit those demands. Product developments and testing were carried out in the commercial production facility in order to improve the current FCF offerings. Actual testing of the FCF innovations was also conducted in supermarkets where FCFs were being sold in order to confirm product improvements. Furthermore, objective instrumental measurements of product odour were determined with the assistance of the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

1.2 Overview of the FCF industry

Fresh-cut products (FCPs) first appeared in the US market in the 1940s (Landi et al., 215), but developed substantially in the 1980s (Rojas-Graü et al., 2011). Since then, the production and consumption of packaged convenience products has spread worldwide. FCPs are whole fruit and vegetables that are minimally processed and packaged in a ready-to-eat form. The market for FCPs has grown due to increasing demand for products characterised with high levels of convenience, nutrient value, safety, natural

[1] https://www.utas.edu.au/tia/arc-training-centre

taste and freshness (James and Ngarmsak, 2010), particularly in industrialised countries (Ferguson, 2016; Landi et al., 2015). FCPs were first introduced in the US, in response to the significant change in consumption patterns of fresh produce (Bunch, 1984). The changes were driven by increased demands for convenience in fresh produce preparation (Resurreccion and Prussia, 1986) and the recognition of the health value of the commodity. Additionally, advances in packaging technology also contributed to the development of FCFs (Shewfelt, 1987). FCPs expanded in Europe and Japan shortly after market introduction in the US (James and Ngarmsak, 2010). They then spread to Korea in 1990 (Kim, 2007) and to Australia, in 1995 (Produce Processing Magazine, 2007).

The market for FCPs has grown in the last 40 years with FCPs sales in the US increasing from US$ 3.3 billion in 1999 to US$ 5.5 billion in 2007 (Cook, 2014). In 2008, however, fresh-cut vegetables (FCVs) had shown a growth trend, while the sales of FCFs have slowed down (James and Ngarmsak, 2010). In Europe, double-digit growth has been observed since inception, but this also gradually declined from 2005 to 2010 at 6 % average, with FCF being more affected (Van Rijswick, 2010). In Japan, sales of FCPs grew from US$ 1.0 billion in 1999 to US$ 2.6 billion in 2005 (Izumi, 2007; Korea Fresh-cut Produce Association, 2006), with a majority of sales (89 %) in FCVs (Kim, 2007). Stagnant growth of sales in FCPs, however, was observed until 2010, when the retail sales rose again (Kashiwagi, 2014). The growth rate of FCP sales in Korea has similarities with that of Japan's (Kim, 2007) with FCVs being the major category (75.4 %) (Kim, 2007). In the latest available data, the retail sales of FCFs declined by 3 % from 2013 to 2015 (Statistica, 2019).

In summary, FCPs particularly FCFs, have grown rapidly worldwide since inception, but have experienced limitations in commercial success. The causes of the decline in FCF markets need to be understood to guide future product development.

1.3 Research drivers in the FCF industry

The instability of market growth in the FCF industry, as covered in Section 1.2, remains a present challenge, which could be addressed by improving the product development process. Product development is an effective strategy for any food company to build its competitive advantage and long-term financial success in the global food market (Costa and Jongen, 2006; Winger and Wall, 2006). Product innovation, as a result of the product development process, maintains the growth of the company and its stakeholders. Moreover, product innovation spreads the market risks, enhances the stock market value and increases the competitiveness of the company (Buisson, 1995; Lord, 2000; Meulenberg and Viaene, 1998). Identifying the factors that influence market turbulence, and then adapting through changes in product development for FCF innovation that address identified factors may increase FCF sales success.

Market volatility in the FCF industry occurs as a result of changes in the demand or supply side of the chain. The demand side is driven by the constantly changing value perceptions of the end-users (Landi et al., 2015). These changes range from basic considerations, such as improving food safety, shelf life, and reducing wastage, to demands for increasingly sophisticated foods having special characteristics in terms of nutritional value, palatability, and convenience (Winger and Wall, 2006). How the end-users measure their value perceptions also varies over time, as they continue to adapt to their changing demographics, socio-economic and cultural environment (Grunert and van Trijp, 2014b). This phenomenon is observed through the shifting of purchase and consumption behaviours of the end-users. In effect, these major changes in demand for food products alter where and how products are processed and distributed (Winger and Wall, 2006).

On the other hand, the market volatility on the supply side, is primarily attributed to the inevitable perishability (~6 d shelf-life) of FCFs (Bertazzoli et al., 2005). Additionally, the advancement in new technologies, changes in food laws and regulations, and competitive environments also trigger market turbulence in the FCF industry (Grunert and van Trijp, 2014b). Furthermore, new social and environmental concerns are bringing pressure for more change in the supply side of convenience food products such as FCFs (Winger and Wall, 2006).

The FCF industry, therefore has to address both demand and supply side factors in order to minimise the market volatility of FCFs. One way to do this is to integrate appropriate market and technical innovation efforts. Consequently, when employed together, these innovation efforts can improve food products (Cardoso et al., 2010; Costa and Jongen, 2006; Earle, 1997). While the demand drives product offerings, the FCF industry can utilise existing appropriate and implementable technology in order to tailor the FCFs. Moreover, certain business models can also be applied in order to deliver the improved FCFs to the customer in a secure manner (Winger and Wall, 2006).

1.4 Conceptual framework for the thesis research

While an integrated market and technical innovation for product development are ideal, most of the FCF industry has focused only on either innovation in developing or innovation in commercialising FCFs. One of the main reasons has been cost. The implementation of both innovation approaches entails a high cost, commitment and effort, which is usually difficult and challenging to achieve (Costa and Jongen, 2006). Thus, for market innovation, extensive reliance on market trends derived from online or Internet-based tools (Schaarschmidt and Kilian, 2014) is more significant than actively engaging consumers for the product idea generation. Current competing products are also utilised as a benchmark for product conceptualisation and development (Costa and Jongen, 2006). "Me-too" product copying syndrome also dominates in the food industry including FCF industry. This usually results in an incremental change and very high failure rate for new products that do not successfully address consumer needs (Winger and Wall, 2006).

In some cases, the FCF industry also applies technical innovation of FCFs in order to improve the product quality and extend shelf-life. Changes in the business environment, such as the availability of new technologies, ingredients or package forms or the alterations in the distribution channels or exportation can lead to application of technical innovation (Costa and Jongen, 2006). New legislative regulations and restrictions can also trigger product reformulations and process modifications in product development (Costa and Jongen, 2006). Technological innovation is perceived as the source of ground-breaking product innovation compared to market innovation (Schaarschmidt and Kilian, 2014). Thus, it has become a conventional practice in the food sector, including the FCF industry. The FCF industry has utilised various postharvest technology developments in order to continuously improve the quality and shelf-life of FCFs since the 1980s.

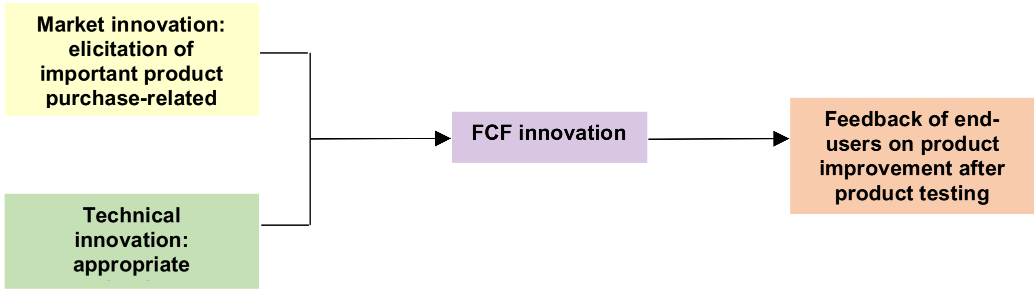

Fig. 1.2. General conceptual framework on product development approach for FCF innovation.

To date, the evidence showing the success of integrating market and technological innovation in the product development process is inadequate. Empirical studies showing that these approaches are more successful than the traditional strategy of using technology as the sole source of innovation are limited (Costa and Jongen, 2006). This research, therefore, is driven to propose, develop and test the integration of market and technical innovation in order to improve the success of FCFs in the market (Fig. 1.2).

The market and technical innovation can be integrated through a consumer-led product development approach. This approach is focused on the concept of delivering authentic added-value goods to the consumers (Grunert et al., 1996; Lord, 2000; Trijp and Steenkamp, 1998; Urban and Hauser, 1993). A consumer-led product development approach can be achieved by translating the needs of the end-users into product specifications, industrialising production and commercialising products (Costa et al., 2004; Grunert et al., 2008). The proposed product development approach for FCFs, therefore is an interaction between consumer expectations and demand, the emerging knowledge from horticultural science and postharvest technology and the technical capacity of the FCF industry.

The consumer-led product development approach can be categorised, based on the information source and familiarity to the stimuli (Van Kleef et al., 2005). The categorisation types can either be need or product-driven. These types of approaches, together with the task format methods, determine the response or actionability for marketing or technical development. While the need-driven type often leads to the development of new product types, the product-driven type improves the existing product (Van Kleef et al., 2005). In this case, FCFs as the product in focus, is an existing product and therefore the product-driven type of product development approach is more appropriate. Specifically, the product development approach proposed focuses on improving the product based on the important information from the end-users such as demands and perceptions for the product. This approach also validates the product improvement through actual testing with current and potential end-users. Consumer involvement is therefore necessary at specific stages of the product development process (Fig. 1.2). The response of consumers serves as a source of information in the idea generation stage, co-creation in the design and development stage, and user-feedback in the testing stage (Nambisan, 2002).

1.5 Industrial objective, scope and limitations

1.5.1 Industrial objective

The industrial objective was set broadly by the industrial sponsor as research to understand the consumer drivers for purchase of FCFs, and be able to deliver innovations that would increase sales and offerings. This was interpreted as research to improve the product development process by developing and testing an approach for industrial applications in order to innovate FCFs with improved perceived value.

1.5.2 Scope

The research, by industry request, was focused on FCFs because of the challenges involved in maintaining fresh-like quality during prolonged shelf-life periods (Soliva-Fortuny and Martín-Belloso, 2003). FCFs are easily perishable after harvest due to their soft texture, high physiological activity, high sensitivity to microbial spoilage as well as mechanical injury, which limit the market potential and consumer access (Lu et al., 2018; Zhang et al., 2015). Therefore, it was necessary to seek methods to prolong the shelf-life and maintain quality of fruit during postharvest handling (Belay et al., 2018). Fresh-cut watermelon (FCW) was selected as the test model by the industry sponsors because of the increasing demand of end-users and the highly perishable nature of the product. Watermelon is perceived as a refreshing and sweet fruit, a favourite fruit snack or a dessert, especially in warmer days by the end-users. The whole watermelon, however, has an excessive weight of two to three kg, and therefore, a ready-to-eat form is more convenient. FCW quality maintenance, however, is limited to only a six-day shelf-life. For commercial production, this shelf-life period is short, considering that the finished products are sent to a distribution centre and stored up to three days before they are distributed to the retail markets. The industry determined that a 20 % shelf-life extension of FCW to eight days, with end of shelf-life sensory quality acceptable to the end-users, would therefore benefit both the FCF industry and the end-user. This, therefore was set as a target for the research.

1.5.3 Limitations

The extent of experimental research for the thesis was governed by the ease of access to information required for testing the proposed product development approach. Primarily, the information needed came from the current and potential end-users of the FCFs. The target market for these products in Australia are the large cities such as Sydney, Melbourne and Brisbane. While there may be significant difference in consumer responses in the various cities in different states, the population in this study, however, was restricted to Sydney as the largest market for FCFs. Furthermore, Sydney was also a strategic location for conducting the research as the facilities of the partner industries, distribution centre, retail markets and the research institution collaborator were available within the area.

The research was focused on determining how the postharvest factors, specifically post-cut treatments, influence the quality of FCFs, which excludes the pre-harvest factors. This limitation was offset by utilising high quality raw fruit for product development and testing from approved suppliers. High quality in the case of watermelon, refers to matured produce with absence of physiological defects and total soluble solids (TSS) that is between eight to ten per cent. These raw material specifications were measured by the quality assurance and control team of the industry partner. The research experiments, therefore followed this protocol.

The implementation of the proposed product development research was dependent on the timing and availability of resources of the industry partner. The time to conduct the innovation cycles of development and small-scale testing was governed by the schedule of the daily operations in the commercial facility and willingness of the in-house panel to participate. The in-house panellists of the industry partner include staff that do not work directly on the processing of the FCFs in order to avoid the risk of extreme familiarity to the product. In addition, the number of innovation cycles (ICs) that could be conducted was limited only to the three permitted by the available time. However, three ICs were sufficient in order to produce improved FCFs that could be perceived by the end-users.

1.6 Thesis Outline

The thesis is comprised of six chapters. The structure of the thesis was developed from presenting the research gap in Chapter 2, how the gap was addressed in Chapters 3, 4, and 5, and the thesis conclusion and implications in Chapter 6. A brief description of each chapter is presented below.

Chapter 2 deals with the review of literature relevant to the innovation approaches applicable to the improvement of FCFs. This chapter provides the studies on product development approaches, the technical and market innovations carried out for FCFs, and the gaps in the research areas. The theories and methodologies in these studies were identified and reviewed for their application in the development and testing of the PV innovation model for FCF innovation. The development and testing of each phase of the model were presented in the next three research chapters.

Chapter 3 is the first research chapter which presents two studies related to value perceptions and related product cues of the FCFs. This chapter identified the motivations and deterrents for purchasing and consumption of FCFs (Study 1). The value perceptions and related product cues of the FCW as the test product were also determined (Study 2). The key findings in this chapter, particularly the intrinsic cues of FCW were translated into product characteristics. These product characteristics were used to guide the technical innovations presented in Chapter 4. The extrinsic cues of FCW derived from this study were used in developing actual formats of FCW which were tested in Chapter 5.

Chapter 4 is the second research chapter, which showed how technical innovation cycles were carried out for FCF innovation. The investigation of the effects of modified atmosphere packaging technology (Study 3), mint leaves inclusion (Study 4), and post-cut sanitation spray (Study 5) on the flavour quality and consumer acceptability of FCW were presented in this Chapter. The correlations of sensory quality to objective measurements used for the continuous improvement of the product were also presented in this chapter. The improved FCW prototypes were developed into actual formats that were tested in Chapter 5.

Chapter 5 is the last research chapter. It illustrates how both market and technical innovation efforts were integrated for delivering FCFs with improved perceived value. This Chapter also presents the usefulness of integrating choice experiments with informed consumer sensory testing (Study 6) in order to holistically confirm the perceived value improvement of FCW. These tests were performed through the simulated stages of purchasing, consumption, and repeat purchase decision. The outcomes presented in this chapter provided evidence of the PV innovation model as a practical and effective tool for FCF innovation.

Chapter 6 concludes the thesis and provides a discussion on its relevance to industrial application and contribution to the body of knowledge in the area of product development. This chapter also provides limitations of the PV innovation model innovation of FCFs and other food products. Future undertakings for further research were also supplemented in this chapter.

Chapter 2 Theoretical framework of the PVI model

Chapter 2 presents the review of key literature underpinning the theoretical framework of the thesis required to improve the innovation of FCFs. This review focuses on the examination of appropriate postharvest technology applications for improving the quality of FCFs and the available consumer research tools to identify factors that are mostly influencing value perceptions and purchase of FCFs and other FC products (Fig. 2.1). The research gaps were identified from these two major science areas and the research questions formulated to guide the development of the thesis. The key findings from the review were then utilised as the basis for conceptualising the theoretical framework on the PV innovation model for FCF innovation.

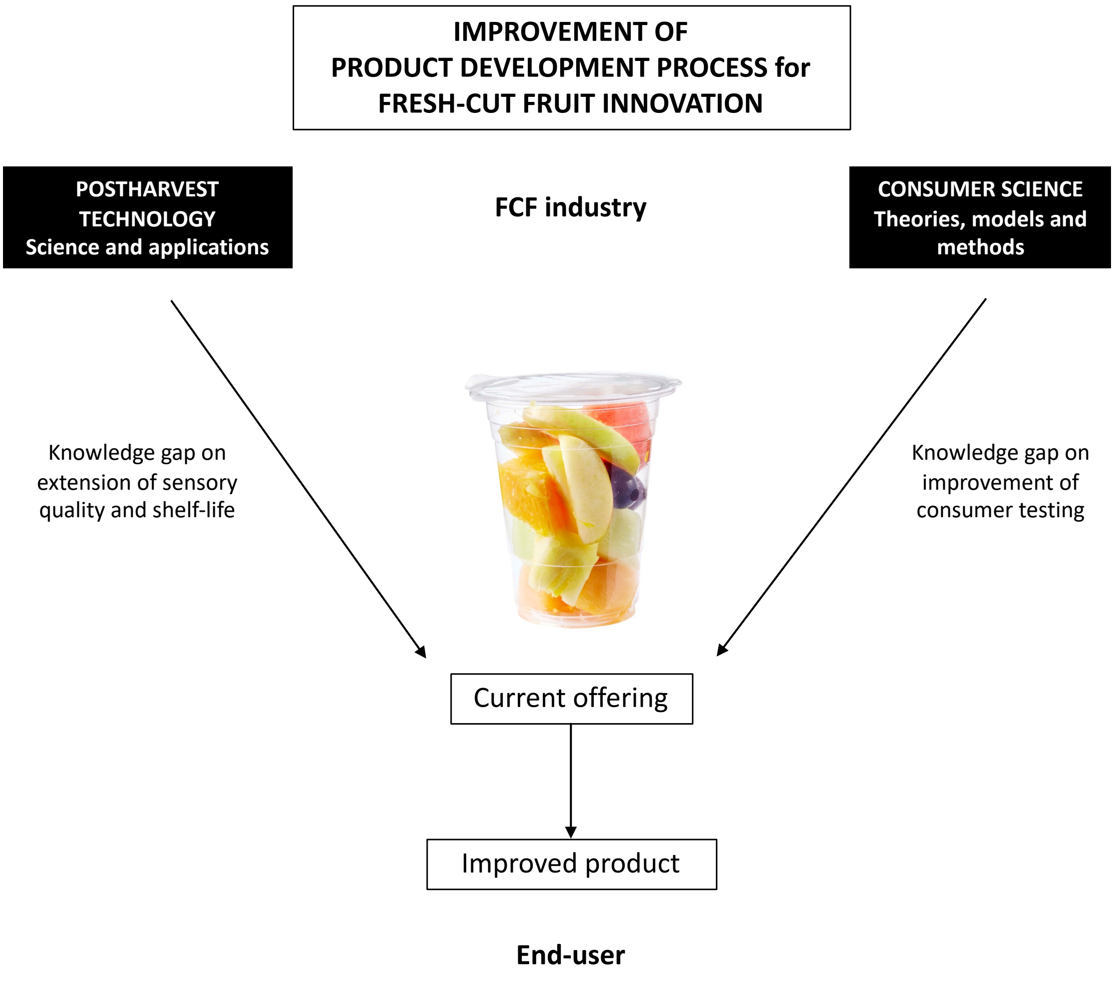

Fig. 2.1. Innovation approaches for the improvement of the product development process.

2.1 Introduction

The suitability of an approach to improved innovation relies on the available resources for the industry partner to tap. Knowledge access through open channels and utilisation of external technology and solutions are some of the opportunities derived from open innovation. Collaboration of the FCF industry with stakeholders such as the universities, government institutions and other key players of the FCF supply chain is considered as an open innovation approach (Saguy and Sirotinskaya, 2014).

Improving postharvest technologies and shelf-life is an inherent aspect of developing better FCF products. Established postharvest processing and packaging techniques from literature such as those presented in Amaro et al. (2015), need to be examined in order to identify appropriate techniques for product improvement. They need to increase the perceived sensory quality and extend the sensory shelf-life of FCFs. Sensory shelf-life is the length of time when the changes in the sensory characteristics of a product, as perceived by the consumers, are still acceptable (Giménez et al., 2012). In this regard, consumer involvement in the technological innovation to estimate the sensory shelf-life of FCFs is required. The objective effects of postharvest techniques on the perceived sensory quality and extension of the sensory shelf-life of FCF must be determined to select approaches that will result in improved consumer perceptions of the quality.

Information derived from target markets is useful in guiding innovation (Ronteltap et al., 2007). Consumer science review is required in order to identify and understand factors influencing purchase and consumption. Consumer research provides an in-depth understanding of the needs of consumers, the translation of those needs into product requirements, and consumer product testing (Moskowitz and Saguy, 2013). The applicability of studies in consumer food behaviour, perceptions and important product cues of FCFs needs to be examined to understand approaches for improvement of the innovation process. In addition, the suitability and applicability of the testing methods utilised to determine changes in product perceptions, preference, and product acceptability after introducing innovation need to be assessed in order to test the effectiveness of improved innovation approaches.

2.2 Innovation approaches involving end-users in product development

Innovation is essential to gaining a competitive advantage and creating value. Its outcomes can either be new products or new processes (Saguy, 2011). Product innovation provides differentiation and is apt for aggressive and competitive food markets (Suwannaporn and Speece, 2010). Process innovation, on the other hand, leads to organisational success, high performance and survival of any company (Bigliardi and Galati, 2013). When innovation is applied into the product development process, both outcomes are achieved. Essentially, the product development process is composed of three phases, namely: idea generation, product design and development, and product testing. The involvement of consumers in each phase is ideal in order to ensure the delivery of consumer-effective products.

Consumer involvement is a market-oriented product development process for enhancing consumer acceptance and for promoting successful market introduction and diffusion of the innovation (Urban and Hauser, 1993). Six types of innovation approaches that involve the end-users, have been reviewed by Busse and Siebert (2018). All are linked to open innovations that tap consumers or the end-users as the source of information to guide innovation (Busse and Siebert, 2018; Guiné et al., 2016). The innovation approaches include: "want-find-get-manage" model (WFGM) (Slowinski, 2006), living labs (LL) (Wolfert et al., 2010), crowdsourcing (Oliveira et al., 2010), quality function deployment (QFD) (Costa et al., 2000) , technological road mapping and consumer-led new product development.

The WFGM framework is an innovation approach that involves an interaction within the company in running their internal commercialisation process (Slowinski, 2006). The approach is spearheaded by the managers who should know what they "want" to access and "find" them externally. Consequently, they have to "get" it contractually and "manage" all of these activities and resources in order to achieve success in their innovation (Slowinski and Sagal, 2010). The WFGM model considers consumer needs and demands, and hence is linked to open innovation. However, this model is limited by using only specific tools for consumer involvement (Busse and Siebert, 2018).

“Living labs” for innovation is another proactive and user-centric approach to open innovation applied in evolving real-life and application contexts (Wolfert et al., 2010). It is a strategic and systematic approach that builds on sensing, prototyping, validating and refining complex solutions by using the end-user as a co-designer of innovations in a real-life setting. In food, living labs have been applied in public consumption situations such as bars and restaurants (von Wirth et al., 2019).

Crowdsourcing innovation is an innovation process where large online networks of consumers are utilised in order to gain external knowledge about trends and technologies (Oliveira et al., 2010). It refers to the various practices and activities that are mainly web-based and often use social media. This type of innovation is win-win-oriented for both the “crowdsourcer” and the “crowd” or the consumers (Djelassi and Decoopman, 2013). Crowdsourcing, however does not involve an active consumer involvement and does not clearly outline how to integrate the consumer into the process (Busse and Siebert, 2018).

Quality function deployment (QFD) is a structured innovation approach that controls the product development process and focuses on customer satisfaction in order to deliver new products (Costa et al., 2000). This innovation approach consists of product planning, product design, process planning and the process control planning phases. Among these four phases, consumer involvement only occurs in the first phase which makes up the “house of quality”. The “house of quality” resembles a house, which consists of rooms that are sequentially filled in order to translate product requirements of consumers into specific product characteristics. The product requirement data are gathered through market research, recorded customer complaints, focus groups, interviews, surveys and conjoint analysis (Chan and Wu, 2002; Costa et al., 2000). The QFD approach may be focused on achieving consumer satisfaction. However it does not necessarily support feedback from the end-users at the later stage of product development as in prototyping or market introduction (Kaulio, 1998).

Technological road mapping is a useful approach that coordinates the development process and the market introduction of innovations and is typically used in strategic planning (Phaal et al., 2007). A time-based and multi-layered chart which is used to guide innovations is the outcome of this approach. The road mapping process involves the inputs of the key players of the industry. A focus group discussion method can be used to elicit inputs from the key players (Specht et al., 2015). Consumers, or the end-users, may have an impact on the planning. However, they are not actively involved in the road mapping process (Busse and Siebert, 2018).

Consumer-led product development is a market-oriented innovation approach that integrates the needs and wants, as well as the feedback of consumers in the product development process (Costa and Jongen, 2006). Consumer elicitation methods for needs and wants (Van Kleef et al., 2005) and for product validation (Grunert et al., 2010) are available to carry out the consumer-led product development approach. Examples of methods that elicit the needs and wants are the laddering method, focus group discussion, free elicitation and the Kelly repertory, which are generally interview techniques (van Kleef et al., 2005). On the other hand, conjoint analysis, and importance-performance analysis (Grunert et al., 2010) are examples of the product-driven techniques that are useful to elicit feedback from end-users.

2.3. Postharvest technology applications and testing

The industrial processing associated in the production of FCFs normally induces plant tissue injury that causes potential detrimental effects on the nutritional and sensory quality of FCFs (Yousuf et al., 2018). Fruits are living and respiring products. The physical injury from the processing steps hastens its active metabolism resulting in high quality losses that limit consumer appeal and market potential (Lu et al., 2017; Opara et al., 2017; Zhang et al., 2015). Biochemical changes, such as faster respiration and enzymatic and microbial activity can occur (Caleb et al., 2012; Mahajan et al., 2008). Subsequently, these biochemical changes are translated into discolouration, water soaking, softening, flavour change and off-odour development depending on the fruit type and cultivar. Therefore, appropriate postharvest techniques must be employed to prevent undesirable biochemical changes and microbial activity in FCFs.

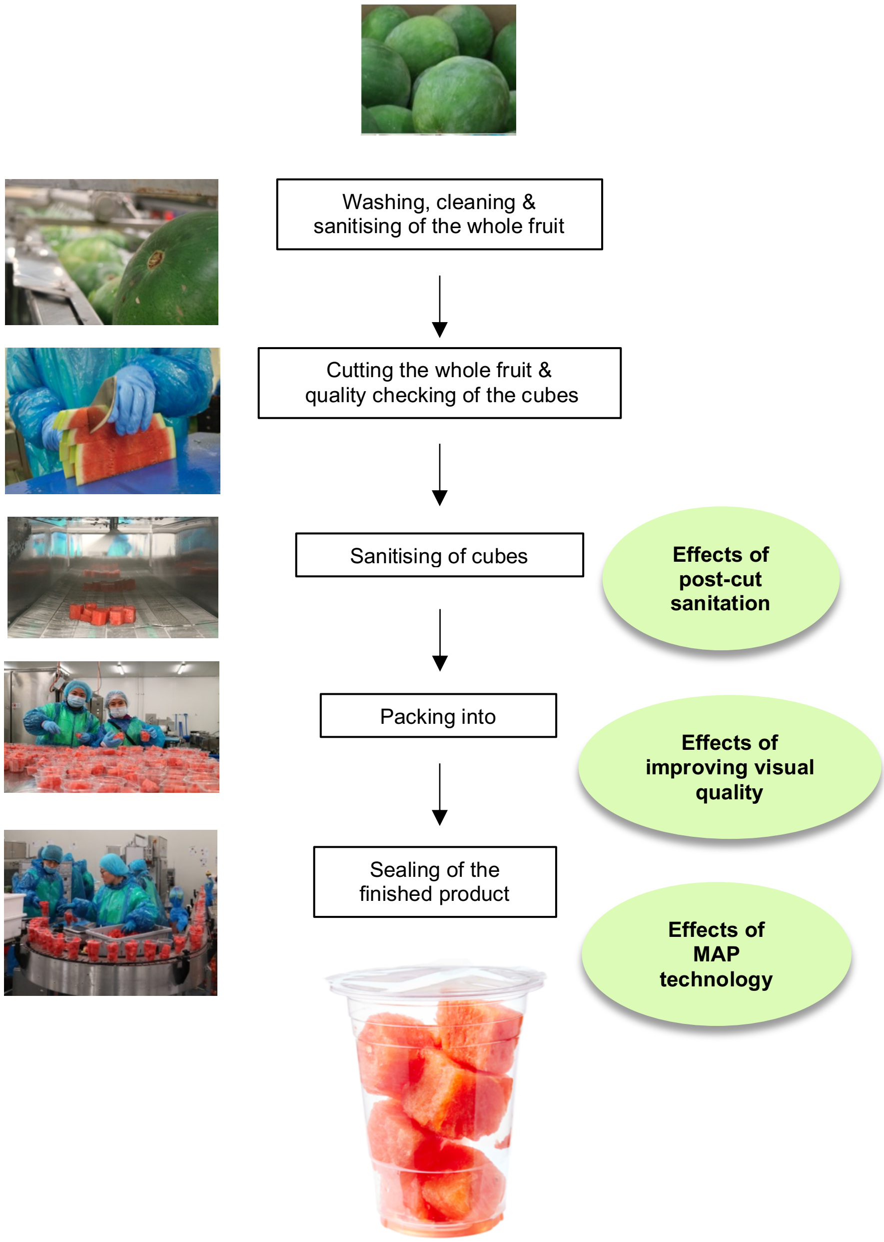

Fig. 2.2. An example of a FCF process flow.

Postharvest techniques are applied to processing and packaging steps of the FCFs. An example of the sequential operations, starting with washing and disinfection of the whole fruit is shown in Fig. 2.2. The postharvest techniques that can be applied thereafter include the utilisation of various post-cut sanitation treatments, enhancement of visual and flavour cues for FCFs and modified atmosphere packaging (MAP) technology. These postharvest techniques may prevent or supress the occurrence of the biochemical changes. Thus, the sensory quality of FCFs products is maintained, the sensory shelf-life is prolonged and losses due to spoilage are reduced.

2.3.1 Postharvest processing and packaging techniques

2.3.1.1 Effects of post-cut sanitation treatments

Post-cut sanitation is mainly applied to reduce the risk of pathogenic microbial contamination and lower the rate of spoilage thereby promoting a longer microbial shelf-life of FCFs. However, changes in flavour and appearance are detected prior to the occurrence of visible microbial growth and perceptible decay of FCFs. These changes in flavour and appearance, therefore, limit the sensory quality and shelf-life of FCFs. The sensory quality remains a critical factor to the end-users in the repeat purchase (Suchánek and Králová, 2019). Therefore, it is necessary to investigate the effects of post-cut sanitation on the sensory quality of FCFs in addition to microbial shelf-life extension.

Various post-cut sanitation methods that can be applied for the improvement of the sensory quality and microbial shelf-life of FCFs are reported in the literature. These methods differ in nature. The methods can be classified as chemical-based (Table 2.1), physical-based (Table 2.2), and others including biological-based (Table 2.3). Chemical-based methods are also known as antimicrobial washing solutions. Antimicrobial washing solutions are the most common methods of post-cut sanitation application (Bahram-Parvar and Lim, 2018) as they are inexpensive, easy to apply and effective in reducing microbial load. Antimicrobial washing solutions include the use of peroxyacetic or peracetic acids, chlorine dioxides, organic acids, ozonated water, electrolysed water and natural antimicrobials (Table 2.1). Physical-based methods such as UV radiation and vapour treatments are also gaining popularity due to effectiveness in maintaining microbial quality and sensory quality of FCFs without added chemicals (Table 2.2). Biological-based methods, such as the use of bacteriocins, bacteriophages, lactic acid bacteria, yeast and moulds are deemed natural and are used as control agents of spoilage and pathogenic microorganisms (Table 2.3).

Table 2.1. Chemical-based post-cut sanitation treatments and effects to FCF sensory quality.

Treatment	Parameters	Type of FCFs	Effects on sensory quality	Objective measurements	Subjective measurements	Other effects	Reference
Chemical sanitisers & bacteriocin	Peracetic acid, H_2O_2, nisin, EDTA, ClO_2, NaOCl	Cantaloupe/ rockmelon	Delayed softness, no “off flavour”	pH, TSS, TA, colour and firmness analysis	Quality-based test (9-pt hedonic scale) with 5 trained assessors	Low microbial growth	Silveira et al. (2008)
Chemical sanitisers	H_2ClO +/- Ca chelate (i.e. Ca propionate, $CaCl_2$, or Ca amino acid)	Honeydew	Maintained firmness, surface colour & appearance	Surface colour, texture, volatile analyses with SPME	Preference & acceptability test with 395 consumer panellists	Low microbial count & inhibited respiration rates	Saftner et al. (2003)
Chemical sanitisers	H_2O_2	Pineapple	Flesh firmness	pH, TSS, TA, colour & firmness analyses	Acceptability test (5-pt hedonic scale) with 10 trained assessors	No significant effect on microbial quality	Nur Aida et al. (2011)
Weak acid	Lactic acid & ascorbic acid	Strawberry	Good appearance & no off-odour	Colour & texture analyses	Quality-based test (10-pt intensity scale) with 8 trained assessors	Low microbial growth	Pérez et al. (2014)
Acidified electrolysed water (AEW)	AEW with distilled water or 2 %NaCl	Pineapple	Firm and no off-odour	pH, TSS, TA, vit C colour & firmness analyses, juice leakage determination	Acceptability test (9-pt hedonic scale) with 5 trained assessors	Low microbial growth	(Raiputta et al., 2012)
AEW	AEW with Ca ascorbate	Apple	Less browning and firm	Colour & firmness analyses	Quality-based test (5-pt intensity scale) with 7 trained assessors	Low microbial growth	Wang et al. (2007)
Ozone	Gaseous ozone under vacuum	Cantaloupe/ rockmelon	Maintained visual aroma & firmness quality	Colour, texture & TSS/SSC analyses	Quality-based (5-pt intensity scale) & acceptability (9-pt acceptability scale) tests with 4 trained assessors	Reduced *Salmonella* count	Selma et al. (2008)
Ozonated & chlorinated water	Ozonated water vs active chlorine	Pear	Maintained colour	pH, colour & TSS analyses	Quality-based (5-pt intensity) & acceptability (5-pt acceptability) tests with 8-10 trained assessors	Reduced of microbial & no significant effect on TSS & pH	Abreu et al. (2012)
Chemical sanitisers & bacteriocin	Peracetic acid, H_2O_2, nisin, EDTA, ClO_2, NaOCl	Cantaloupe/ rockmelon	Delayed softness, no off- flavour	pH, TSS, TA, colour and firmness analysis	Quality-based test (9-pt hedonic scale) with 5 trained assessors	Low microbial growth	Silveira et al. (2008)
Chemical sanitisers	H_2ClO +/- Ca chelate (i.e. Ca propionate, $CaCl_2$, or Ca amino acid)	Honeydew	Maintained firmness, surface colour & appearance	Surface colour, texture, volatile analyses with SPME	Preference & acceptability test with 395 consumer panellists	Low microbial count & inhibited respiration rates	Saftner et al. (2003)
Chemical sanitisers	H_2O_2	Pineapple	Flesh firmness	pH, TSS, TA, colour & firmness analyses	Acceptability test (5-pt hedonic scale) with 10 trained assessors	No significant effect on microbial quality	Nur Aida et al. (2011)
Chemical sanitisers	1-methylcyclopene	Cantaloupe	Maintained surface colour & appearance, softer texture	TSS, TA, colour & firmness analyses, antioxidant & total phenolics analyses	None	Maintained metabolic rate, concentration of phytochemicals	Amaro et al. (2013)

Table 2.2. Physical-based post-cut sanitation treatments and effects to FCF sensory quality.

Treatment	Parameters	Type of FCFs	Effects on sensory quality	Objective measurements	Subjective measurements	Other effects	Reference
Ultraviolet radiation	UV-C: 4.79 kJ m^{-2}	Watermelon cylinders	Very slight juice leakage; some off-odour development	Lycopene & phenolics content analyses	Quality-based (5-pt intensity scale) & acceptability (9-pt acceptability scale) tests with trained assessors	Reduced microbial growth & retained lycopene and phenolics content	Gómez et al. (2015)
Ultraviolet radiation	UV-C: 3.2 kJ m^{-2}	Dragon fruit	Maintained firmness, flesh colour & sensory attributes	Colour, texture, & TSS/SSC analyses	Acceptability test (9-pt hedonic scale) with 6 trained assessors	Reduced microbial growth	Nimitkeatkai and Kulthip (2016)
Sustained deficit irrigation and postharvest vapour	Vapour treatments for 7-10 s at 95 °C	Pomegranate arils	Less browning, high colour quality & no significant change observed in other sensory attributes	TA, pH, SSC, colour, firmness, electron microscopy analyses	Quality-based (5-pt intensity scale) with 7 trained assessors	Low microbial load & Water saving (6-11%)	Peña-Estévez et al. (2015)
High pressure processing	600 MPa for 10 min and subsequently stored at 4°C	Cantaloupe	Maintained TA & °Brix, low colour quality	vitamin C, *β*-carotene TA, °Brix & colour analyses	None	Low vitamin C (depending on cultivar), increased β-carotene	Wolbang et al. (2008)

Table 2.3. Other post-cut sanitation treatments and effects to FCF sensory quality.

Treatment	Parameters	Type of FCFs	Effects on sensory quality	Objective measurements	Subjective measurements	Other effects	Reference
Enzymatic peeling (EP) vs vacuum peeling (VP)	Enzymatic solution of Rapidase C80 Max Citrus (for EP) & vacuum pulses (for VP)	Orange	High visual liking in EP orange; high integrity (low water loss & instrumental texture)	pH & SSC analyses	Quality-based (5-pt intensity scale) test with7 trained panellists & acceptability test (9-pt hedonic scale) with 60 consumer panellists	Extended microbial shelf-life in EP than in VP	Barrios et al. (2014)
Edible coating with essential oils (EO)	Alginate based edible coatings containing thyme and oregano	Papaya	Maintained colour, texture, juiciness but declined taste and flavour due to penetrating flavour & taste of EO	pH, SSC & TA analyses	Acceptability test (9-pt hedonic scale) with x consumer panellists	Reduced microbial load, slow pH change, delayed organic acid consumption & reduced respiration rate	Tabassum and Khan (2020)
Osmodehydration & pectin edible coating	Sucrose solution containing Ca lactate & pectin	Cantaloupe /melon	Maintained colour and firmness, reduced weight loss but masked melon taste	TA, colour & structural analyses	Acceptability test (9-pt hedonic scale) with 35 consumers	Inhibited microbial growth	Ferrari et al. (2013)
Natural antimicrobials	Vanillin & cinnamic acid	Cantaloupe / melon	Acceptable vanilla flavour	Vitamin C analysis	Acceptability test (9-pt hedonic scale) with 9 trained assessors	Reduced respiration rate & microbial growth, retained vitamin C	Silveira et al. (2015)
Natural antimicrobials	*(E)*-2-hexenal, hexanal, citron essential oil (packed in MAP: 7 %O_2 and 0 %CO_2)	Apples	Retained colour and firmness	Volatile profile, electric nose colour & texture analyses	None	Extended shelf-life without detrimental effects in safety retained volatile profiles	Siroli et al. (2014)
Bio-based packaging, microperforated	Polylactic acid with peelable microperforated lid	Cherries	Maintained red colour, texture, flavour & overall quality rating	Colour, firmness, TA, SSC & volatile analyses	Acceptability test (9-pt hedonic scale) with 100 consumers	Reduced fungal decay	Koutsimanis et al. (2015)

Chemical-based methods are the most common practice and do not require high capital equipment costs. Table 2.1 presents the effects of various chemical-based post-cut sanitation treatments on the sensory quality of different FCF products. These data were derived from the studies published from 2000 to 2019. The effectiveness of each post-cut sanitation treatment is produce-specific. For instance, the use of ozonated water is effective in maintaining the overall quality of FC rockmelon or cantaloupe (Botondi et al., 2016) and pear (Abreu et al., 2012) but it showed no additional value in maintaining the firmness of FC kiwi (Beirao-da-Costa et al., 2014). Each method also requires optimisation of concentration or dose to maximise the benefits to microbial control and minimise any adverse effects on sensory quality or shelf-life. An example is the concentration of peracetic aid applied to rockmelon or cantaloupe. While 100 mg L^{-1} of peracetic acid dipping medium has resulted in the translucency of rockmelon and in off-odour development (Botondi et al., 2016), a reduction of 20 mg L^{-1} delayed the onset of softness of the fruit (Silveira et al., 2008). Therefore, treatments must be optimised to maximise the benefits to sensory quality aside from its microbial quality.

2.3.1.2 Enhancing the sensory quality of FCFs

Demand for natural and high quality FCFs with an extended shelf-life period is increasing (Silveira et al., 2015). Plants, herbs and spices are some of the common natural ingredients used to add flavours and extend the microbial shelf-life of FCFs. Plants and herbs such as oregano, garlic, parsley, sage, coriander, rosemary, and lemongrass are sources of essential oils which are known to have antimicrobial effects (Gutierrez et al., 2008; Holley and Patel, 2005; Proestos et al., 2008). Essential oils from culinary herbs and spices are GRAS (generally recognised as safe) but should not be extracted from the listed prohibited and restricted plants and, should only be used in minute amounts as flavouring agents (FSANZ, 2017). Essential oils have been shown to control a wide range of pathogenic and spoilage bacteria in FCFs (Gutierrez et al., 2009). The antimicrobial activity of the essential oils is due to the hydrophilic functional groups such as hydroxyl groups of phenolic compounds (Dorman and Deans, 2000). Essential oil can be applied as a washing sanitising solution (Gutierrez et al., 2009), spray (Anthony et al., 2003; Ponce et al., 2004) or coating with edible films (Sipahi et al., 2013; Tabassum and Khan, 2020) (Table 2.3). Essential oils can also be incorporated into active packaging for the same preservation purpose through a number of techniques such as vaporisation of volatile compounds inside the package (Melgarejo-Flores et al., 2013), inclusion of auto-adhesive labels with essential oil (Montero-Prado et al., 2011), application in filter paper (Wrona et al., 2015) or gauze (Guillén et al., 2007), and direct incorporation or coating on the plastic polymer (Martiñon et al., 2014; Muriel-Galet et al., 2012).

Essential oils also have intense aromatic properties due to their volatile compounds (Ha et al., 2008). The strong and distinct scent of essential oils, however, may cause undesirable changes to the flavours of FCFs and limit their usage (Silveira et al., 2015). The flavour compatibility and acceptability of FCFs and essential oils, therefore must be considered based on consumer studies (Baranauskienė et al., 2006). Good flavour combinations can increase product value and acceptability while FCF quality is maintained (Ayala-Zavala et al., 2009). The sweet, fresh flavours of fruits like watermelon, apple, strawberry, pineapple, mango continue as FCFs (Kader, 2008). These flavours may be compatible to consumers when mixed with sweet and fresh flavours of herbs like cinnamon, clove, basil, and peppermint (Ayala-Zavala et al., 2009).

2.3.1.3 Effects of modified atmosphere packaging technology

Modified atmosphere packaging (MAP) technology is a widely applied postharvest packaging technique in the food industry for maintaining the quality of fresh and fresh-cut food products (Zhang et al., 2015). This technology is desirable for industrial applications because it is inexpensive, easily applicable, and compatible to a wide range of production and packaging machinery (Spencer, 2005). MAP is considered an efficient technology as it significantly prolongs shelf-life and hence, extends the distribution potential of products. In FCFs, the cut fruit contained in plastic polymeric films are exposed to a desired atmosphere through modification of the gas composition (Banda et al., 2015; Beaudry, 2000; Belay et al., 2018). MAP packaging that displaces air by the desired gas during packaging results in the rapid formation of favourable conditions for reducing or preventing physiological and biochemical changes (Belay et al., 2017). This active MAP involves flushing of gas or introduction of desired gas mixture of CO_2, O_2 and N_2 or other inert gases after pulling a slight vacuum in the pack (Vermeiren et al., 1999). The technique utilises only atmospheric gas components, leaving no toxic residue on the product and hence, has achieved public acceptance (Belay et al., 2019).

Modification of gas in the package can be achievable by passive methods. Passive MAP is the natural change of the gas composition in the pack resulting from the respiration of produce and gas permeability of the packaging. While active MAP has the advantage of controlling the initial gas composition, the application of passive MAP is easier and cheaper. Either way, the aim is to achieve a gas mixture that prevents or lessens metabolic changes of FCF products, such as softening, pigment degradation and senescence (Beaudry, 2000). The choice of application method in an industrial setting depends on factors such as the type and nature of produce and its respiration rates, packaging type and permeability, and capacity of packaging machinery (Beaudry, 2000).

An additional consideration in MAP is determining the optimal concentrations of gas mixtures. The tolerance level of produce to gas concentrations in active MAP varies. Understanding the limits is critical to maximising the effectiveness of the technology. Table 2.4 shows the effects of initial modified atmosphere on the sensory quality of various FCFs. For example the studies of Belay et al. (2017) and Maghoumi et al. (2014) on FC pomegranate arils showed that high O_2 concentration inhibited microbial growth, prevented anaerobic respiration and reduced product decay. When applied to grapefruit however, high levels of O_2 promoted the production of reactive oxygen species that damaged the cytoplasm and eventually caused deterioration of grapefruit quality (Chaudhary et al., 2015). Similarly, very low levels of O_2 have different effects on various produce. Low concentration of O_2 inhibited the rate of oxidation which maintained the desirable flavours of FC guava in the study of Teixeira et al. (2016). However, this low O_2 level induced anaerobic fermentation, which led to off- flavour and off-odour development in fresh-cut pears, in the study of Li et al. (2012). Elevated CO_2 concentration, on the other hand may induce flesh injury that could result in discolouration and texture loss (Teixeira et al., 2016).

The response to various gas concentrations is produce-specific. It is therefore necessary to determine the effects of gas combinations on each product (Lu et al., 2018). In addition to produce type, the packaging material including lidding films and storage temperatures also significantly influence the effectiveness of MAP (Kader and Ben-Yehoshua, 2000). Controlled levels of perforation in the lidding films of the packaging may be required to allow gas permeability and maintain the optimal gas concentration in the package. Gas composition may also be modified by using packaging and films with varying permeability. Perforations, however, are less expensive, easier to manipulate to achieve desired gas composition for specific produce type and reproducible for commercial production. Changes in gas concentrations are strongly affected by temperature. Maintaining a strict cold chain during storage, transport and retail distribution is therefore necessary to prevent microbial proliferation and quality deterioration (Caleb et al., 2013). Overall, the integration of product, package and storage environment is required to maximise the benefits of MAP systems and its application to the FC industry.

Table 2.4. Modified atmosphere packaging and their effects on the sensory quality of FCFs.

Parameters	Type of FCFs	Effects on sensory quality	Objective measurements related to sensory quality	Test and type of sensory panel	Other effects	Reference
70 kPa O_2 + 10 kPa CO_2 + 85 kPa N_2 Storage: 12 d, 5 °C	Pomegranate arils	Retention of colour and firmness	Firmness and colour analysis; SPME GC-MS volatile analysis	None	Lower microbial activity, highest composition and amount of volatile compounds	Belay et al. (2017)
80 kPa O_2, 20 kPa N_2 and Hot treatment at 45 °C Storage: 14 d, 4 °C	Pomegranate arils	Retention of appearance, taste and odour	pH, TSS and TA analysis	5 trained panellists; 5-pt scale on appearance, dehydration, off-odour and taste (1= extremely bad, 5= excellent)	Lower decrease in antioxidant activity and phenolic compounds, indicating lower levels of tissue damage and disruption; lower levels of enzymatic browning; TA and TSS, remained constant during the shelf life.	Maghoumi et al. (2014)
60 kPa N_2 and 30 kPa CO_2, 10 kPa O_2 and 30 kPa CO_2. and 70 kPa N_2 Storage: 21 d, 4 °C	Mango	Highest postharvest performances in terms of weight losses, TSS, TA, crunchiness, juiciness and fruit flesh decay	Weight loss, TSS and TA analysis	10 semi-trained sensory panel; 10-pt scale on appearance, firmness, aroma, off-flavour development and overall acceptance (1= absence,10= full intensity)	Improved the retention of the antioxidant capacity	Liguori et al. (2018)
5 %O_2 and 5 %CO_2; 30 %O_2 and 5 %CO_2; 80 %O_2 and 20 %CO_2 Storage: 12 d, 4 °C	Pear	Stable surface colour in high O_2 packaging, anaerobic respiration in low O_2 packaging	Colour analysis, vitamin C analysis, phenolic, anthocyanin and antioxidant capacity analysis	Appearance, taste, and texture were scored on a 9-pt intensity scale (1= poor, 9= fully characteristic); overall acceptability (1= inedible, 9= excellent)	High phenolic content in high O_2 packaging, high vitamin C content in low O_2 packaging	Li et al. (2012)
5 kPa O_2 and 5 kPa CO_2 Storage: 28 d,12.2 °C	Guava	Retention of colour and taste	Colour and firmness analysis, pH, TSS, TA, SPME GC-MS analysis	5-pt scale evaluation of appearance (1= extremely bad, 5= excellent)	Retardation of fruit ripening	Teixeira et al. (2016)
70 %N_2, 10 %O_2, 20 %CO_2 Storage: 9 d, 10$\pm$1 °C	Ananas, Mango Orange	Retention of organoleptic attributes and no off-flavours	None	9 semi-trained sensory panel using a descriptive test and a 9-pt rating scale (1= worst and 9 = best)		Sortino et al. (2017)
10 kPa O_2 and 10 kPa CO_2 Storage: 8 d, 4 °C	Nectarines	Preserved the sensory quality of FC nectarines	pH, TSS, TA, SPME GCMS Analysis	Trained panellists; descriptive profiling using; Quantitative Descriptive Analysis	Preserved more volatiles	Cozzolino et al. (2018)

Research across both postharvest processing and packaging needs to be integrated in order to maintain the sensory quality and extend the sensory shelf-life of FCFs. The research can be implemented through combining multiple steps as there is no single technology that can effectively promote and maintain the overall product quality (Ghidelli and Pérez-Gago, 2017). Hurdle technology consists of an effective 'step-by-step combination' of different techniques and methodologies to preserve the freshness and structure of FCF (Rahman et al., 2011; Trias et al., 2008). FCFs are usually developed using multiple methods such as cold storage, MAP, chemical control, ethylene occurrence control, plastic film packaging, and sealed packaging techniques (De Corato, 2019). Selection of these hurdles for FCFs requires individual evaluation as their effects on quality attributes are product specific (Rico et al., 2007).

2.3.2 Methods for testing the effects of postharvest techniques on sensory quality

The effects of the postharvest technology applications on the sensory quality of FCFs can be tested objectively or subjectively. Sensory quality is not considered an intrinsic property of the food, but rather a result of the interaction of human beings to food (dos Santos Garruti et al., 2012). However, sensory quality directly relates to intrinsic characteristics of the food such as the acid and sugar contents, cell structure and pigments, which can be measured objectively. More common in research papers is the use of analytical measurements in order to objectively test the effects of the postharvest techniques on sensory quality attributes. On the other hand, the sensations perceived by humans, as a result of food intake and interactions, allows for the subjective measurements of the sensory quality of the food. Sensory evaluation is a common practice and is the subjective counterpart of analysing the effects of postharvest techniques on the sensory quality attributes of FCFs.

2.3.2.1 Objective methods

Objective measurements such as the analysis of titratable acidity, pH, total soluble solids (TSS), texture and colour are commonly performed in order to test the effects of the postharvest applications on the sensory characteristics of FCFs (Tables 2.1 to 2.4). Titratable acidity and pH analysis provide the objective measurement of the acid concentration contained in the FCFs, which has an impact on the product flavour (Sadler and Murphy, 2010). TSS analysis approximates sugar concentration in FCFs

(Sadler and Murphy, 2010), and thus determines the sweetness level of the FCFs. The visual quality of FCFs can be objectively analysed using texture analyser and colourimeter. While the texture analyser provides an objective measurement on the firmness of the fruit pieces, the colorimeter shows any deviation of their colour (Tables 2.1 to 2.4).

The effects of the postharvest techniques on all the sensory quality attributes of the FCFs were typically determined in the studies reviewed except for the odour quality (from Tables 2.1 to 2.4 only 5 out 27 studies). Odour, together with flavour quality is critical to consumer acceptance of FCFs. Besides, the sensory quality deteriorates faster than visual quality and is thus a good indicator of freshness. The effects of postharvest techniques on odour quality can be determined using solid phase microextraction gas chromatography-mass spectrometry (SPME GC-MS). SPME GC-MS provides a semi-quantitative determination of the volatile compound concentrations. These are responsible for the odour quality of the FCFs. Other analytical instruments such as gas chromatography-mass spectrometry olfactometry (GC-MS-O) and proton transfer reaction-mass spectrometry (PTR-MS) can also be used to perform the volatile measurements in the FCFs. GC-MS-O was used to identify the odour active compounds (OACs) in newly cut FCW (Genthner, 2010). PTR-MS was used to rapidly determine the volatile profile of fresh-cut apples that were subjected to different postharvest treatments (Ciesa et al., 2013).

Research on the effects of the postharvest processing and packaging application can therefore be tested by focusing on the volatile measurements in order to objectively assess FCF quality. GC-MS-O can be used to identify the differences between OACs of fresh and end-of-shelf life stored FCFs. OACs can serve as markers of freshness in testing samples and the change in the volatile profile of the sample would reflect the effects of each postharvest technique applied in the innovation process. PTR-MS may be used to rapidly examine the volatile profile of FCFs. The difference in the volatile concentration on the other hand could be determined using the SPME GC-MS. However, research to test the practicality and efficiency of these volatile measurements for evaluating the effects of the postharvest techniques objectively is required.

2.3.2.2 Subjective methods

Subjective measurements in testing the sensory quality characteristics of FCFs are carried out using sensory evaluation techniques with humans acting as either a sensory instrument or a consumer respondent. A sensory evaluation technique is often described as a scientific method used to evoke, measure, analyse and interpret those responses to foods as perceived through human senses. Sensory evaluation techniques such as descriptive, discriminatory test and affective tests are typically classified based on the purpose of testing and role of humans in the test. Descriptive and discriminatory tests, for example, are performed in order to establish product profile and improve existing products, respectively.

Affective, hedonic or consumer sensory testing, on the other hand is performed in order to determine liking or acceptability of the product. Sensory characteristics such as appearance, odour, flavour and texture are the important attributes that contribute to the perceived quality of food products including FCFs. These sensory characteristics can be measured in terms of the degree of liking using the 9-point hedonic scale developed by Peryam and Pilgrim (1957). Acceptance measurements can be done on single products and do not require a comparison to another product (Lawless and Heymann, 2013; Meilgaard et al., 2006). Hence, this testing does not require training of panellists. Moreover, panellists in this test are also utilised to mimic real-life consumers.

Sensory evaluation techniques are also used in order to estimate the sensory shelf-life of the product. Sensory shelf-life is the period for which a food product can be stored and its sensory quality remains acceptable. It is determined by the consumers who find product quality falling short of their expectation that eventually leads to non-purchase (Labuza and Schmidl, 1988). Sensory shelf-life can be estimated using a number of existing methodological approaches. Giménez et al. (2012) conducted a review of the four sensory shelf-life estimation methods, which included quality-based, acceptability limit, survival analysis and cut-off point. They emphasised the necessity of performing consumer studies in order to establish the sensory shelf-life of food products and therefore, estimations should be based on consumer perceptions (Giménez et al., 2012).

Quality-based methods are the most common food industry practice in estimating product shelf-life. Examples of quality-based methods include difference from control, intensity of sensory attributes and quality ratings. The shelf-life estimation based on these methods is typically carried out by quality assurance personnel who are trained and experienced in the standard product quality. This shelf-life estimation type utilises a basic storage sampling design where a large set of samples is stored and tested at various storage times (Lawless and Heymann, 2010). Product shelf-life is estimated based on the deviation from the organoleptic quality standards of stored products. Although these methods are easy to implement, they are not representative of consumer response and hence provide insufficient information to gauge product purchase (Table 2.5).

The acceptability limit method reflects the period at which respondents notice the first significant difference in the sensory characteristics with respect to the fresh sample (Giménez et al., 2012) (Table 2.5). This period of noticing the first significant difference in samples is determined statistically as the method only requires the consumers to indicate their liking for the product and not to evaluate its difference from the fresh sample. The samples are presented monadically and panellists need not be trained to carry out the testing. The method typically utilises a reverse storage design (Hough 2006), which allows for performing the consumer testing all at once. All samples stored at different periods, including the fresh one, are tested at the same time. The respondents, however may experience fatigue in doing the task. Fatigue in sensory testing can lead to results that are significantly different from when they have sufficient rest in between sample testing. In addition, the reverse storage design in this shelf-life estimation method may be problematic depending on the type of product samples tested (Hough 2006). In the case of fruit samples, the variability of sensory characteristics increases when raw materials come from different batches. Therefore, the basic experimental storage design is rather ideal.

Table 2.5. Sensory shelf-life estimation methods

Method	Design of sample preparation	Parameters of testing and scale	Type and number of respondents	Sensory shelf-life based on	Advantage	Disadvantage	Reference
Quality-based	Basic storage sampling	Intensities of sensory characteristics; intensity scale (e.g. 1 to 5 with 1 as lowest and 5 as highest)	Trained panellists, typically quality assurance and control personnel; n <10 respondents	Deviation of product quality from standard	Low number of respondents needed; standardised products	Challenge in selection of sensory criteria; not representative of consumer response and hence limited information on product liking and acceptability	Costell (2002)
Acceptability limit	Reverse storage sampling	Sensory quality: visual, odour, taste, flavour and overall; 9-pt hedonic scale	Consumer panellists; number depends on standard errors	Predetermined overall liking score	Quick elicitation of response	High number of consumer response required; fresh sample could have quality rating; sensory fatigue	Hough et al. (2006)
Survival analysis	Basic or reverse storage sampling	Product acceptance or rejection for consumption	Consumer panellists: n> 120 respondents	Percentage of consumers disliking the product	Representative of consumer response	High number of consumers required; complex statistical method of analysis	Hough et al. (2003)
Cut-off point	Basic storage sampling	Intensities of sensory descriptors and sensory quality using 9-pt hedonic scale	Trained panellists, typically quality assurance and control personnel; n<10 respondents; consumer panellists: n> 50 respondents	Predetermined overall liking score and intensity of sensory defect/descriptor	Easier to evaluate samples using trained panellists; allows correlation of data to consumer response	Requires at least 6 sensory studies to establish cut-off point, hence costly; challenge to identify sensory descriptors that relates to consumer rejection	Ramírez et al. (2001)

The sensory shelf-life in the acceptability limit method is estimated as the time required for the overall liking score to fall below a predetermined value. The average overall liking scores for each sample are plotted against storage time, and a linear regression is performed. The predetermined value or acceptability limit is set depending on the type of samples and the conservative level of the food company for quality assurance and control. Giménez et al. (2008) used the overall liking score of six (6 = *like slightly*) as the acceptability limit for whole pan bread, which indicated the consumers also enjoyed the product. The quality limit at five (5 = *neither like nor dislike*) and below is less strict (Giménez et al., 2012). The studies of Capita et al. (2018) and Tsironi et al. (2019) used this overall liking score as the quality limit in determining the shelf-lives of ostrich meat and sea bass fillets, respectively.

Variations in estimating the sensory shelf-life of products are high as there are no robust guidelines on setting a predetermined value of acceptability limit. The limit could be extremely short and conservative for the food manufacturer (Giménez et al., 2007), leading to challenges during handling and distribution. The number of panellist required for the acceptability limit test depends on the analysis of variance. Hough et al. (2006) have provided computation guidelines.

The survival analysis method focuses on the product being rejected by the consumers rather than on product deteriorating in order to estimate the product shelf-life (Hough et al., 2003) (Table 2.5). The advantage is that responses are representative of the consumers. However, running the method to higher number of consumer panellists can be expensive. In this method, consumer panellists are asked if they would normally consume each of the product samples presented to them. These product samples may either be presented to the consumer panellists in a single session, as in a reverse storage design (Giménez et al., 2007), or given one at a time as in the basic storage design (Lareo et al., 2009). The method involves a set of statistical procedures for the analysis of time when changes in the trend of product acceptance occur (Giménez et al., 2012). The complexity of the statistical procedure however, can be a drawback in using this method.

The cut-off point method is a combination of acceptability limit methodology and quality-based intensity measurement and thus, involves both the consumer and trained panellists (Table 2.5). It allows for correlating consumer responses to the intensity of product sensory descriptors. The defect of this sensory descriptor is plotted against the overall liking scores in order to determine the cut-off point. The method requires a minimum of six consumer studies to establish the cut-off point according to Giménez et al. (2012). Nonetheless, the number of consumer studies needed will depend on the consistency of the cut-off point that is determined by each study. The identification of the critical sensory descriptors in the cut-off point method is crucial and, therefore, must be carefully selected. Samples can be stored at different storage periods (Gambaro et al., 2006) or subjected to accelerated storage in order to identify the critical product sensory descriptors (Lareo et al., 2009). Care, however must be considered in subjecting samples to accelerated storage since product changes may vary between high and normal storage temperature (Robertson, 2006). The shelf-life of FCF is 5-7 days, which is relatively short (Stranieri and Baldi, 2017). Thus, accelerated storage may not be required for shelf-life estimation of FCW when subjected to different postharvest techniques. Research to determine the sensory shelf-life of FCW using a basic sample preparation design can therefore be carried out.

Among all the sensory evaluation techniques, the cut-off point method is deemed as the most appropriate method. This method considers both consumer responses and the expertise of the trained panellists to ensure standardisation of sensory quality of the products.

2.3.2.3 Combined objective and subjective methods

Objective methods of testing sensory quality are combined with subjective methods in order to provide a holistic approach in improving product quality and estimation of shelf-life (Wibowo et al., 2018; Yang and Boyle, 2016). The applications of combined analytical and sensory tests have improved the understanding of the relationship of chemical composition to sensory properties (Yang and Boyle, 2016). In understanding natural flavour assessments, human responses are utilised to calibrate instrumental analysis (Martens et al., 1994) or volatile measurements.

2.4 Product-related factors influencing attitude and behaviour and test methods

Understanding important product factors influencing the attitude and behaviour of end-users is necessary in order to develop and provide consumer-effective products. Attitudinal measures commonly involve the assessment of affective responses, such as liking or disliking, pleasantness or unpleasantness, desire or need to select or eat foods. Behavioural variables include measures like choice, purchase, and consumption. Attitudinal variables are typically the antecedents of the behavioural variables of product purchase and consumption. The satisfaction or dissatisfaction after food consumption forms the perception towards the product and hence, affects the motivation or deterrent to buy and consume again (Olsen, 2002). Consequently, when the consumer is presented with the same product or product with similar attributes again, s/he bases her/his purchase and consumption decision on her/his formulated perception (Zauner et al., 2015).

2.4.1 Product perceptions and product cues

The assessment of consumer perceptions towards food is of paramount importance in the development and marketing of products (da Silva et al., 2014), which also holds true for FCFs. One of the most studied concepts of consumer perceptions for food products is that of value and risks. Value perception relates to the trade-offs between product benefits and costs (Zeithaml, 1988) and is typically formed during or close to when purchase occurs. Additionally, tangible product benefits such as convenience and freshness are experienced right away. Higher value perception leads to increased purchase motivations or product preference (Sanchez-Fernandez and Iniesta-Bonillo, 2006) and once confirmed during consumption, results in higher customer satisfaction. Additionally, the perception of product necessity positively influences the value perception for the product. However, it does not necessarily contribute to increasing consumer satisfaction (Makanyeza et al., 2016).

In contrast, risk perception may be formulated at the time of purchase but its effects are usually long term (Sweeney et al., 1999). The concern on the long-term effects of food safety on health is a good example of risk perception in food. An example of the long-term effect is not consuming the food or even its substitutes for a prolonged period of time regardless of its benefits (Cuite et al., 2007). The relationship between value and risk perceptions are inversely proportional where higher risk perception decreases value perception, which often leads to deterrents of purchase repeat purchase (Mwencha et al., 2014). Research to focus on increasing the value perceptions of FCFs is required.

2.4.1.1 Perceived value, its nature and conceptualisation

Understanding and assessing the perceived value of consumers is essential for product development. Customer value is a key predictor of consumer choice (Cronin Jr et al., 2000). Therefore, the understanding and assessment of the perceived value may assist in developing consumer-effective products. The perceived value concept is subjective and, therefore, should not be solely determined objectively by the producer (Eggert and Ulaga, 2002). Moreover, it is context-dependent (Woodall, 2003) and therefore varies depending on the situation when the product is purchased and consumed. Additionally, perceived value is perceptual (Sanchez-Fernandez and Iniesta-Bonillo, 2006). It involves trade-offs (Graf and Maas, 2008) of benefits and costs, internal and external standards, as well as existing alternatives (Eggert and Ulaga, 2002; Holbrook, 1994). It therefore is relevant to deliver authentic products that perform as expected.

The perceived value concept can also be understood and assessed based on how it is formed. Zauner et al. (2015) conducted a review on PV conceptualisation. Their findings focus on the three different stages of its conceptualisation. These stages include the unidimensional construct, multidimensional construct and construct based on context. The unidimensional construct of PV refers to how consumers evaluate the PV of the product and is therefore, vital in order to design consumer-effective products such as FCFs. Following the conceptualisation of Zeithaml (1988), PV is defined as the overall evaluation of consumers on the product benefits based on the perceptions of what is received and given in order to acquire the product (Fig. 2.3). This definition presents the economic and cognitive nature of PV (Zauner et al., 2015) whereby the purchase decision is based on the maximum product benefits (Sánchez-Fernández and Iniesta-Bonillo, 2007) and existing alternatives (Gale et al., 1994). From this definition, it can also be inferred that the perceived value is conceptualised during the product purchase (Fig. 2.3).

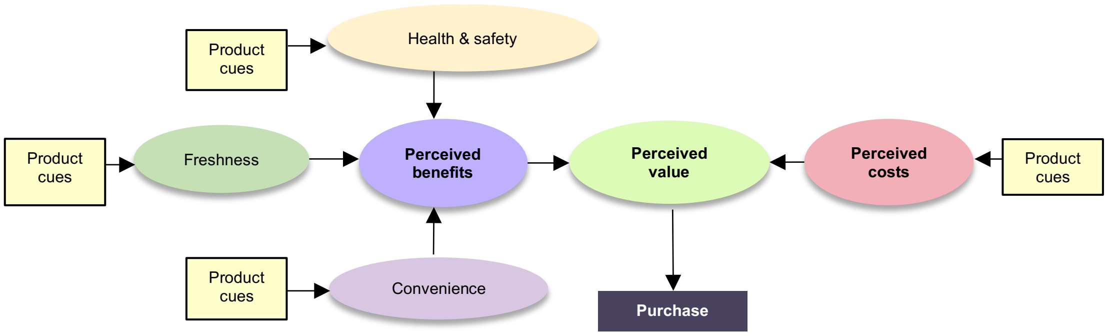

Fig. 2.3. The unidimensional construct of PV in a retail setting.

Note: The diagram is derived from the perceived value concept of Zeithaml (1988).

The scenario is imagined to be happening quickly, especially in a retail setting where the movement of shoppers is fast-paced. A consumer does not spend unnecessary time to evaluate the product prior to making purchase decision. Once s/he has assessed the maximum benefits of the product against its perceived costs, her/his perceived value for the product has been determined. Consequently, s/he buys the product unless product options with higher benefits exist. These scenarios present the cognitive and economic aspects of PV (Zauner et al., 2015).

The limitation of the unidimensional construct of PV has led into the conceptualisation of the multidimensional construct. The studies of Holbrook (1994), Babin et al. (1994), (Sheth et al., 1991) and Sweeney and Soutar (2001) expanded the construct up to the consumption stage (Fig. 2.4). They emphasised the relevance of affective dimensions of PV, which are experienced once the product is consumed. The PV dimensions such as functional, emotional, social and environmental aspects of the consumption process relate to customer satisfaction and repurchase decision. When the perceived value, or the expectations formed prior to or during purchase are met or exceeded during consumption, customer satisfaction is achieved. New positive product experience creates additional dimensions of PV that may significantly influence purchase in the future (Hsu, 2014) (Fig. 2.4).

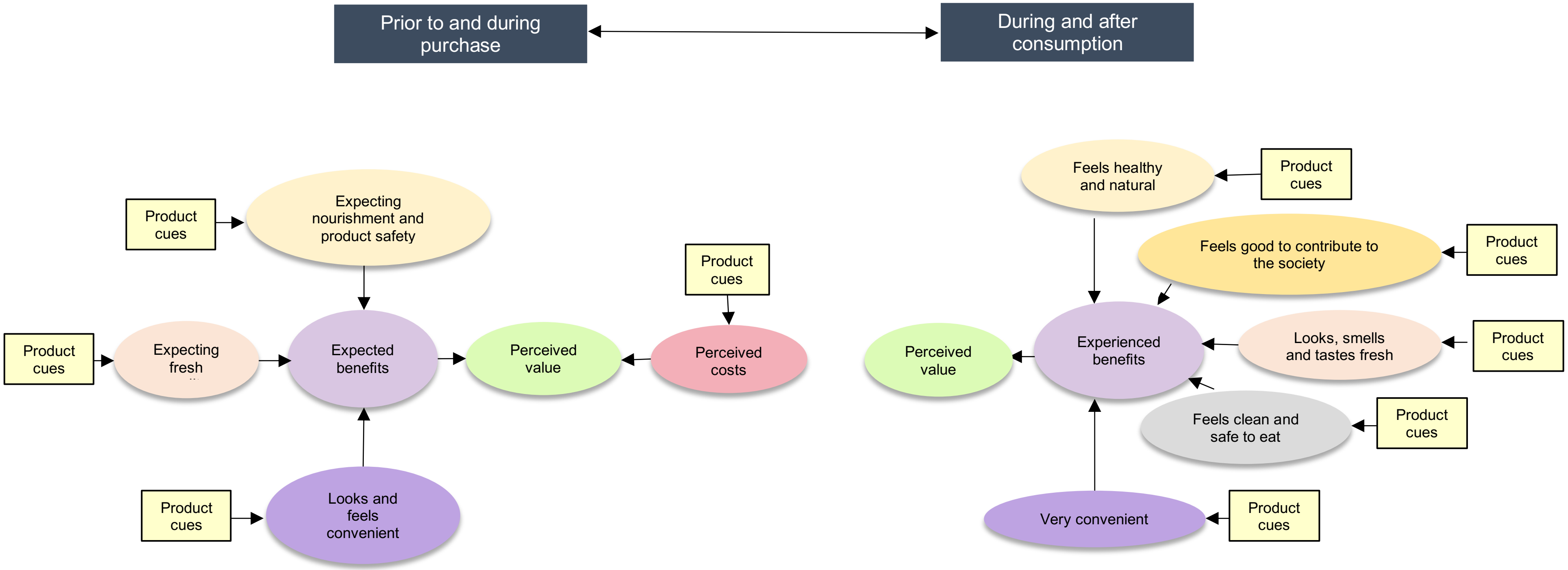

Fig. 2.4. The multidimensional construct of PV.

Note: The conceptual diagram is derived from the perceived value concepts of Zeithaml (1988), Sheth et al. (1991) and Sweeney and Soutar (2001)).

The construction of PV based on context refers to the actual testing and application of PV in real-world scenarios. The challenge in PV conceptualisation lies in whether the value dimensions are considered as independent (Sheth et al., 1991) or interrelated (Sweeney and Soutar, 2001) with each other. The context to which PV concept is applied ultimately guides the decision, nonetheless both perspectives are valid (Baxter, 2009). Further research, however is needed on the role of research context and applicability of product/service value dimensions in understanding the consumer attitudes and behaviour (Zauner et al., 2015). The research to test and apply the multidimensions of PV of FCFs and its influence on the attitudes and behaviour of end-users is therefore required in order to expand the PV conceptualisation.

Additionally, the research efforts to apply both unidimensional and multidimensional constructs of PV in FCFs may be useful to guide its innovation. The outcomes of the multidimensional construct during consumption may assist the FC industry in order to cover all possible important PV dimensions of FCFs. These value dimensions however, should be communicated explicitly in the product cues during purchase in order to achieve product preference (Qasem et al., 2016). For example, intact and evenly coloured cut fruit are indicators of freshness and sensory appeal of FCFs that are most important during consumption. This visual quality of the FCFs should, therefore, be met in the actual product contained in a transparent packaging, as displayed on the retail shelves. Fig. 2.5 shows the different value dimensions of FCPs that are extracted and combined from the consumer studies listed in Table 2.6. Each of the value dimensions of FCPs is associated by consumers to one or several product cues or attributes (Fig. 2.5).

Freshness, product safety and health and naturalness are some of the common value dimensions of FC products (Table 2.6). The product cues assessed as drivers of purchase of FC products that are associated with freshness includes appearance (Massaglia et al., 2019) or absence of defects and integrity of tissues (Chinnici et al., 2019), and expiration or shelf-life date (Massaglia et al., 2019; Stranieri and Baldi, 2017). Shelf-life information, in addition to ingredient information on the label, is also associated with product safety (Dinnella et al., 2014; Stranieri and Baldi, 2017).

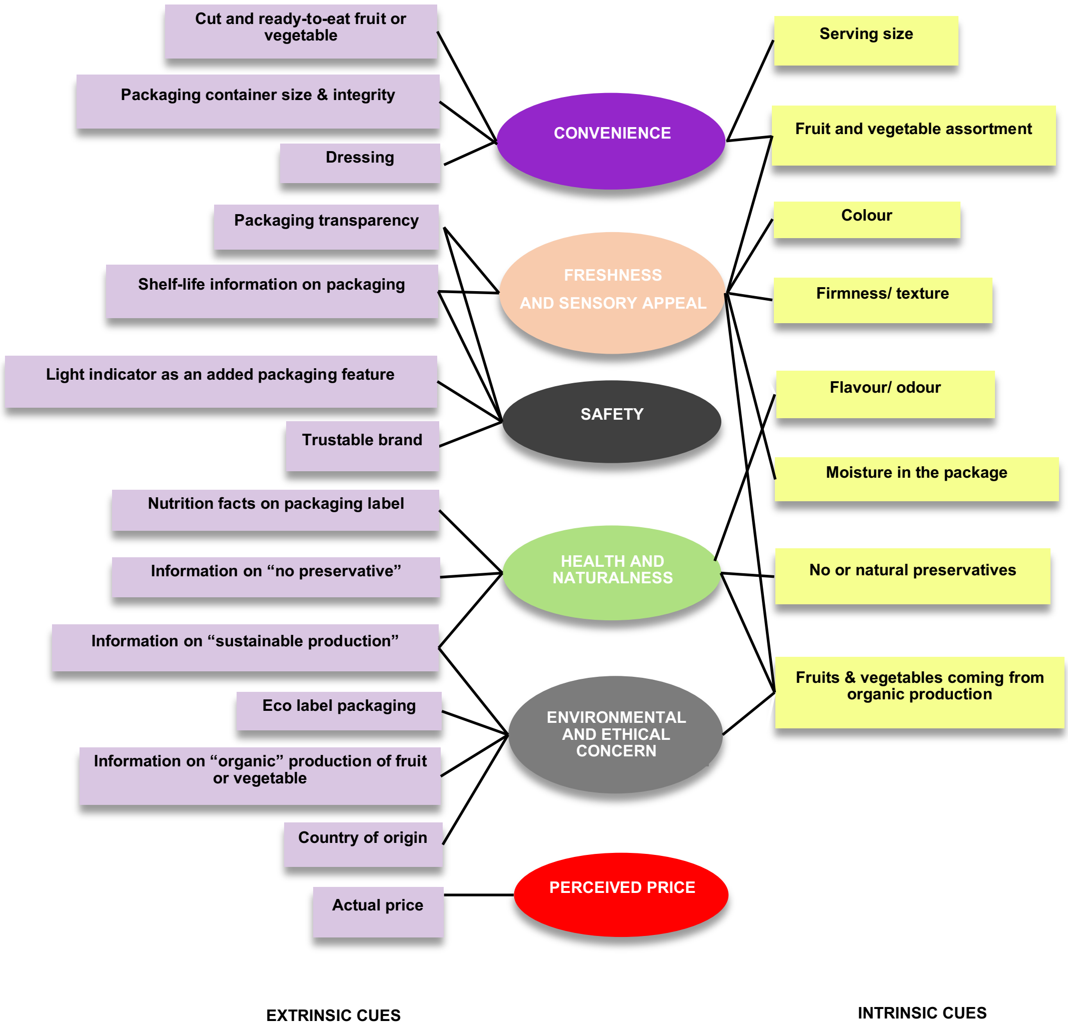

Fig. 2.5. Dimensions of perceived value for FCPs.

The safety of FC salads in the study of Massaglia et al. (2019) explored the attitudes of consumers towards the presence of pesticide residues and genetically modified organisms and microbiological risk. Their findings showed that the consumers perceived chemical safety due to pesticide residues as more important than the other critical elements of food safety. Another important chemical safety risk is associated with the use of preservatives in FCFs. The presence of preservatives, however is a deterrent to purchase (Baselice et al., 2017; Dantas et al., 2004) as consumers expect FC products to be as close as possible to natural or original state (Shewfelt, 1990). Consequently, the product cues related to sensory quality such as taste, flavour, smell, texture and appearance are critical to repeat purchase of convenience products (Brunner et al., 2010; Ragaert et al., 2004) such as FCFs. Sensory signals like rich or full flavour, natural taste, fresh taste, good aroma, and appetising appearance are relevant dimensions of perceived quality (Bonner and Nelson, 1985) which largely constitute perceived value (Zeithaml, 1988). Additionally, the physical appearance of FCFs is associated with health and nutrition (Dantas et al., 2004). Freshness is perceived to benefit health and visual appearance and colour are used to gauge it. Nutritional information on the label is also used to assess the nutritional benefits of the product.

FCPs, aside from their freshness, health and nutritional values, were developed to offer convenience to consumers and hence, this feature is important in buying FC products (Baselice et al., 2017; Bertazzoli et al., 2005; Chinnici et al., 2019; Ragaert et al., 2004; Sanford et al., 2008). The product cues associated with convenience include practicality of use, time saved from preparation, assortment, variety, and add-ons like dressing and the type of packaging (Pilone et al., 2017). Other product cues on the packaging label are associated with various credence value dimensions. For instance, organic certification (Massaglia et al., 2019) and eco-labels (Federico and Sandro, 2015) are associated with the perceived environmental and ethical values of FC products. The product cues like brand and price, on the other hand, may or may not be associated with the overall quality of FCFs and therefore, may or may not influence purchase decision. The study of Massaglia et al. (2019) on the perceptions and preference of FC salads showed brand, but not price, as a discriminating factor in the preference of consumers. In contrast, price but not brand significantly influenced consumer perception and preference findings in the studies of Mayen et al. (2007) for FC rockmelon or cantaloupe and Ragaert et al. (2004) for minimally processed vegetables and packaged fruit.

The relationship of perceived value to product cues in FC products agrees with the Cue Utilization Theory of Olson and Jacoby (1972). According to this theory, products consist of an array of cues that serve as surrogate indicators of quality to the shoppers. The quality perceptions they are referring to largely contribute to the construct of perceived value (Zeithaml, 1988). There is however an acknowledgement of the degree to which consumers associate the given cue with product quality in the Cue Utilization Theory of Olson and Jacoby (1972). Thus, some cues are regarded as more important than the others in the assessment of the perceived value of the product, and therefore should be utilised in the product innovation.

Table 2.6. FC product-related factors influencing the PV of consumers and methods of testing.

Important value dimensions, cues and attributes	Method of data collection & analysis	No. of Respondents	Type of FCP	Country	Objective	Reference
Overall sensory quality	Consumer acceptability test, using 9-pt hedonic scale for 5 different storage period	82	Minimally processed carrots	Italy	Verify the importance of considering the interaction between product and consumer's quality perception	Condurso et al. (2020)
Freshness/ appearance attribute, expiration date and the brand; price, organic certification and food safety; local production and environmental sustainability	BWS approach through interviews at several large-scale retail outlets	620	FC salads	Turin, Italy (northwest)	Explore the preferences and buying habits	Massaglia et al. (2019)
Convenience (practicality of use and time saved in preparation), food safety and healthiness (nutritional information), price and freshness, sensory quality (absence of defects, colour, tissue integrity, flavour and taste)	Face-to-face interview with survey questionnaire in supermarkets and hypermarket	250	FCVs (single and mixed)	Sicily, Italy	Understand the specific aspects of consumer behaviour and the perception of the quality of products that influence the consumption of FCVs	Chinnici et al. (2019)
Food safety, GMO, pesticides,	Online survey	1043	FCPs	US	Examine how consumers perceived different food safety risk factors associated with FCPs and explore the factors associated with consumers' WTP	(Yu et al., 2018)
Packaging innovations (with and without sachets, adsorbing pads)	Consumer sensory test (Likert/hedonic scale)	94	FC cantaloupe with sachets	US	Investigate the impact of a visible sachet inside of a food package on the consumer acceptance of the package and product perception	Wilson et al. (2018)
Tenderness, product preparation (cut type), assortment, brand, organic certification, packaging attributes and vegetable variety	IRI-Infoscan scanner data analysis of 881 FCPs using hedonic price model	881	FC salad	Italy	Evaluate how much Italian consumers pay for FC salad attributes	Pilone et al. (2017)
Freshness and product safety (shelf-life info)	Face-to-face interview	351	FC salads	Lombardy, Italy	Analyse consumers' attitude towards FC salad with an extended shelf-life date	Stranieri and Baldi (2017)
Convenience (with dressing), freshness (packaging with freshness indicator), safety (safety indicator and natural preservative)	Face-to-face interview and DCE, Econometric analysis (Latent class multinomial logit estimates)	1461	FC lettuce	Greece, UK, Italy and Spain	Provide an analysis of consumers' preferences towards FCP novel attributes	Baselice et al. (2017)

Important value dimensions, cues and attributes	Method of data collection & analysis	No. of Respondents	Type of FCP	Country	Objective	Reference
Health and green motivations (eco-label), extrinsic cues (e.g. have fair value, do not require a complex preparation); intrinsic cues (e.g. good for body, healthy, feel good, nutritious, free of chemical residues)	Interview in big malls; Structural equations modelling	425	FCVs	North-east of Italy	Examine the usefulness of integrating measures of motivations in predicting purchase intentions of FCPs	Federico and Sandro (2015)
Freshness (transparency of the pack and appearance of product no moisture in the package, green, undamaged and turgid leaves), safety (expiry date), health (nutrition facts), environmental and ethical concern (information on country of origin)	Repertory Grid Method	81	Ready-to-eat mixed leafy salad	Italy	Identify ten attributes describing consumer's perception of sensory properties of ready-to-eat mixed leafy salad over storage	Dinnella et al. (2014)
Convenience, nutritional value, safe, taste, cost	Self-administered survey	303	FCFs and FCVs	Canada	Determine perceptions	Sanford et al. (2008)
Package, fruit leakage fruit mixes, price, brand	Convenience sampling, face-to-face interview in department stores, Choice-based conjoint	126	FC cantaloupe/ rockmelon	US	Understand consumer preferences for FC melon products	Mayen et al. (2007)
Price (low or high), organic certification label (with or without organic certification, no information), packaging type (expanded polystyrene or polyethylene bag)	Conjoint analysis	96	FC carrots	Brazil	Evaluate effect of label attributes on consumer purchase intention	(De Souza et al., 2007)
Freshness (fresh appearance), safety (guaranteed food safety) and convenience (not having to wash them)	Face-to-face interview with survey questionnaire, Factor analysis (Principal Component Analysis) and Logit regression	792	FCFs and FCVs	Italy	Explore the importance of FC buying attributes to satisfy the needs of the most critical shoppers	Bertazzoli et al. (2005)
Convenience, health, nutritional value, freshness	Face-to-face interview in supermarkets, self-administered factor analysis	294	FCVs and packaged fruit	Belgium	Gain insights in the consumer decision-making process towards minimally processed vegetables and packaged fruits	Ragaert et al. (2004)
Freshness, health (natural, does not have preservatives), safety (label information on hygiene)	FGD (4 sessions)	50 consumers	FC spring greens	Brazil	Investigate the impact of packaging of minimally processed spring greens on consumers' attitude, opinion, thoughts and concepts	Dantas et al. (2004)

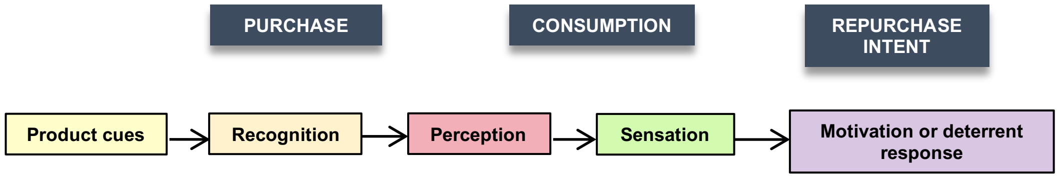

Fig. 2.6. Psychological and behavioural response to product cues.

Understanding how consumers respond to these FCF cues is important for developing effective food marketing and communication strategies (Verbeke and Liu, 2014). This knowledge also assists in developing new product or improving existing products. The consumer responds to product cues by processing this information in the brain through human perception and psychological response (Fig. 2.6).

Product cues are recognised based on the previous experience with the product and other similar products which constitutes the perceptions of the mind. Once the product is experienced through the senses, the mind evaluates whether or not the experience is pleasing. Consequently, positive experience leads to motivation to repurchase and consume more while negative experience, to product rejection and hence, deterrents to purchase. It is therefore vital to identify the product cues that mostly influence the perceptions of consumers to ensure product success in the market.

2.4.1.2 Different product cues and relationship to product characteristics

Identifying the product cues that mostly influence the perceived value for FCFs is vital in order to guide improvement of current FCF offerings. Product cues are sometimes referred to as product attributes. In order to differentiate the two, the following definition is provided. Product attributes refer to the properties or characteristics of food products that are either tangible or intangible and affect consumer buying behaviour (Sijtsema et al., 2002). Product cues, on the other hand, refers to a variety of visual, written and spoken messages of the product. The information provided by the product cues does not actually change the characteristics of the products but it definitely influences the attitudes and purchase decision of consumers (Verbeke and Liu, 2014). To simplify the terms used in this study, the intangible information such as product health and safety are referred to as product attributes while the tangible information such as price information or product colour are referred to as product cues.

Product cues have been identified and classified in order to understand important aspects of the product that influence consumer attitudes and behaviours. The identification and classification of product cues have also been useful in employing research efforts for product improvement. The first classification was based on whether or not the information is inherent to the product. Product cues that are innately embedded in the product such as flavour, colour and taste were referred to as intrinsic cues. Intrinsic cues can only be changed by altering the nature of the product (Olson and Jacoby, 1972). Extrinsic cues are cues outside the product such as price and labelling information. They are considered as product-related but are not taken as part of the physical product (Olson and Jacoby, 1972).

The other classification was based on consumer response during product purchase and consumption. Product cues that are sought for during purchase are referred to as search cues. Examples of this are similar to those of the extrinsic cues. Experience cues are referred to as the product cues during consumption and are therefore similar to the intrinsic cues of the product. A third type of cues, known as the credence cues, are those also sought during purchase, but not evaluated even after consumption. (Darby and Karni, 1973). Examples of these product cues include information or symbols of organic, health and safety certifications. The information provided by these credence cues is a question of faith and trust (Grunert et al., 2004). Nonetheless, they also significantly influence product purchase (Darby and Karni, 1973).

It is essential to gain insight from the product cues that mostly influence the perceived value of consumers in order to develop or improve the product (Sijtsema et al., 2009). However, the terminology used by the consumers to describe their demands must be translated into product characteristics in order to substantiate the desired quality image (Cravens et al., 1988; Neslin, 1981). These specific product characteristics may be utilised by the producers to implement product modification (Steenkamp and van Trijp, 1996). This process, however, requires a multitasking step because the variation and complexity of different characteristics of food products have to be considered (Sijtsema et al., 2009).

The Quality Guidance model of Steenkamp and van Trijp (1996) showed how the quality perceptions of consumer were linked and translated into intrinsic cues and physical product characteristics. The study of van den Heuvel et al. (2007) extended the Quality Guidance model in order to include product credence cues. Research to include the product extrinsic cues is therefore required in order to develop or improve an actual product as it appears in the market. To materialise this research and implement in FCFs, the model of product value design by Armstrong and Kotler (2009) may be useful. The core value of the product represents the main characteristics of the product. These are basically product characteristics related to the intrinsic product cues. The packaging design features, which include labelling, packaging material and brand identity, are the extrinsic cues that constitute elements of the actual product value. The augmented product value and design is composed of product cues that relate to product support services such as warranty and after sales service. These elements of augmented product value are typically common to non-food product goods and are built-in around the actual product (Armstrong and Kotler, 2009).

The classification of product cues in terms of intrinsic and extrinsic cues may be utilised by the FC industry in order to focus their research efforts to improve FCFs (Fig. 2.7). These product cues significantly influence the purchase, consumption and repeat purchase decision of consumers. In the case of FCFs, the main product is visible through the transparent packaging. This type of packaging allows the consumers to see intrinsic cues such as colour, texture and juice leakage even at the point of purchase. Both the intrinsic and extrinsic cues may be translated into physical product characteristics which can be manipulated during product development for FCF innovation (Fig. 2.7). Research is required to identify product cues that mostly influence the PV of consumers in order to improve FCFs.

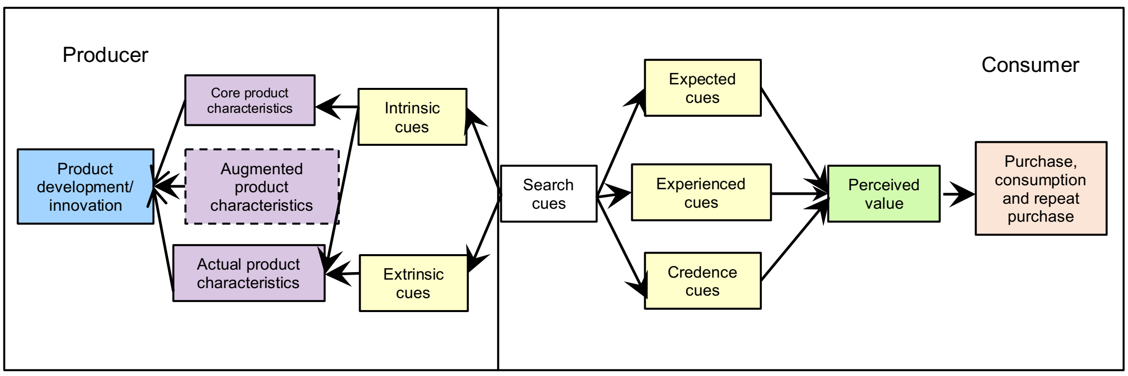

Fig. 2.7. Product innovation approach using product characteristics and cues.

Note: Derived from the concepts of the product design model of Armstrong and Kotler (2009) and Quality Guidance model of Steenkamp and van Trijp (1996).

2.4.2 Methods for identifying product cues and testing PV

The perceived value of consumers varies at different stages of purchase and consumption (Amini et al., 2014), and therefore should be tested at each stage in order to ensure customer satisfaction and repeat purchase. The study of Ares et al (2008) showed evidence of perceived value deviation for FC lettuce. Consumers indicated stricter criteria when selecting products during purchase than at the consumption stage. The reasoning behind the variation is that consumers took into account storing the products prior to consumption and were hence more tolerant to defects once it was purchased. The deviation in perceived value changes may be due to the variation in the consumer evaluative criteria during these stages (Gardial et al., 1994). Perceived value deviation should therefore be investigated in order to address any product concerns and improve the product accordingly.

The product cues that mostly relate to PV may be used to test the variation at each stage and then utilised to improve the product. It is important to identify the most critical product cues that influence the PV of FCFs prior to PV testing. A number of methods to identify these product cues related to PV are extracted from the consumer studies listed in Table 2.6. These methods include consumer surveys conducted through face-to-face interviews in the supermarkets (Chinnici et al., 2019; Massaglia et al., 2019; Mayen et al., 2007; Ragaert et al., 2004), those sent by post or distributed using an online panel (Yu et al., 2018). Conducting focus group discussion (FGD) (Dantas et al., 2004) is also an option in order to elicit important product cues and understand perceptions and motivations for purchase of FC products. All these methods of consumer response elicitation may be utilised in order to guide FCF innovation. Additionally, the effectiveness of the FCF innovation is confirmed through purchase and consumption simulations.

2.4.2.1 Purchase simulation methods

Purchase simulation is a means in research to predict the saleability of products introduced into the market. The common research methods used to simulate purchase intention or preference in FC products (as shown in Table 2.6) are the Discrete Choice Experiments (DCE) (Baselice et al., 2017) or Choice-Based Conjoint Analysis (CBCA) (De Souza et al., 2007; Mayen et al., 2007). These methods are interchangeable and based on the Theory of Consumer Demand developed by Lancaster (1966) and the Theory of Random Utility Model (RUM) by McFadden (1980). According to the former theory, the entire utility in using a product is decomposable in more marginal utilities associated to product attributes or cues. This theory relates to why and how consumers utilise product cues in their assessment of product quality perception according to the Cue Utilization Theory of Olson and Jacoby (1972). The RUM theory, on the other hand, states that the choice of the consumer is based on products with highest utility.

Critical to both DCE and CBCA methods is the identification of product cues and their levels. The study of De Souza et al. (2007) identified the cues and levels of FC carrots by conducting FGD. The selected cues and levels of FC rockmelon in the study of Mayen et al. (2007) were from industry experts while the study by Baselice et al. (2017) relied on literature for the cues and levels of FC lettuce. Once the product cues and levels are established, experimental design is run to create product concepts. Respondents are then asked to go through a series of trade-offs and choose the product concept they are most likely to buy. Quantitative data are generated, which can be subjected to statistical analyses. The output determines which product cue(s) are the most important to the consumers (Jervis and Drake, 2014) and which the industry could utilise and invest in for product development. Additionally, market share may also be simulated, providing information on the product format that would sell best once introduced in the market.

2.4.2.2 Consumption simulation method

A good tasting experience with a food product and consumer satisfaction is crucial for repeat purchase. Therefore, this aspect should be measured through consumption simulation. The common method to conduct consumption simulation is through the sensory evaluation technique known as affective testing or consumer sensory testing. Consumer sensory testing has become fundamental for testing consumer behaviour toward foods. Moreover, it has been used to guide quality assurance, product development and product improvement in the food industry (Cardello et al., 2000).

Consumer sensory testing attempts to quantify consumer perception including PV based on product acceptance or preference through sensory quality cues. The consumer rates the degree of liking for a product on a rating scale (i.e. 9-point hedonic scale) in acceptability measurements while s/he selects her or his product choice in preference measurements. Product acceptability test refers to the integrated judgment of the perceived sensory characteristics of a product (Lawless and Heymann, 2013).This acceptability test is often used rather than a product preference test in conducting consumption simulation because it can also indirectly determine product preference through superior product ratings (Lawless and Heymann, 2013). Consumer panellists need not compare products as they can be assessed monadically. The product acceptability test is typically performed at a central location. In this context, the aim of this consumer test is to determine whether findings in the pilot panel test are the same as with real-world consumers (dos Santos Garruti et al., 2012). The test also explores degrees of liking or disliking. This test, however, requires more time and expense. Thus, it is usually performed by the companies that will actually introduce the product in the market (dos Santos Garruti et al., 2012).

2.4.2.3 Combined purchase and consumption simulation test

Combined purchase and consumption simulation tests are necessary in product improvement studies to ensure market success. They mimic the three stages of purchase processes for food product shopping: purchase, consumption and repurchase (Ballco and Gracia, 2020). Thus, it provides more holistic and realistic information on consumer behaviour toward food in a real-life setting (Köster, 2009) from which product developer and marketers can benefit. With this combined test, the main drivers of consumer preference are easily identified (Næs et al., 2011) and more reliable information on preferred levels of product cues or attributes are acquired (De Pelsmaeker et al., 2013). Additionally, this combined test allows for a more time-efficient product development process as sensory and marketing tests are performed together (Asioli et al., 2017).

A number of studies have used the combined purchase and consumption simulation test in order to understand the interaction of sensory and extrinsic cues in consumer preference. For instance, the study of Endrizzi et al. (2015) investigated the interaction of antioxidant and fibre content in the label information with sensory cues of apple. Their findings showed that, overall, liking was positively influenced by sensory attributes while extrinsic label information only affected health-conscious consumer groups. Label information on price and production process of orange juice, and its interaction with sensory cues, were examined in the study of Menichelli et al. (2012). Similar studies were conducted in a wide range of products such as wine (Veale and Quester, 2009), beef (Baba et al., 2016; Meyerding et al., 2018), yoghurt (Hoppert et al., 2012; Johansen et al., 2010), chocolate (De Pelsmaeker et al., 2017), and bio-fortified orange maize (Meenakshi et al., 2012).

2.5 PVI model - proposed theoretical framework for FCF innovation

The PVI model was developed from the literature review, and proposed for the industrial applications of the industry partner, in order to deliver FCFs with improved perceived value. The thesis was therefore geared towards addressing the core research question: *Is the PVI model effective in developing commercially-produced FCFs with improved perceived value?*

The PV innovation model is a product development approach that utilises the value perceptions and related product cues that are determinants to purchase, as tools to guide product innovation. The foundations of the model were based on Perceived Value Theory, Quality Guidance Model and Cue Utilization Theory combined in a consumer-led product development approach. Hence, the active involvement of the end-users in each phase of the product development process was considered necessary in order to deliver consumer-effective FCFs. The model is divided into three phases, namely: idea generation phase, technical innovation phase and product testing phase (Fig. 2.8). For each phase, a subsidiary research question (SRQ) was formulated.

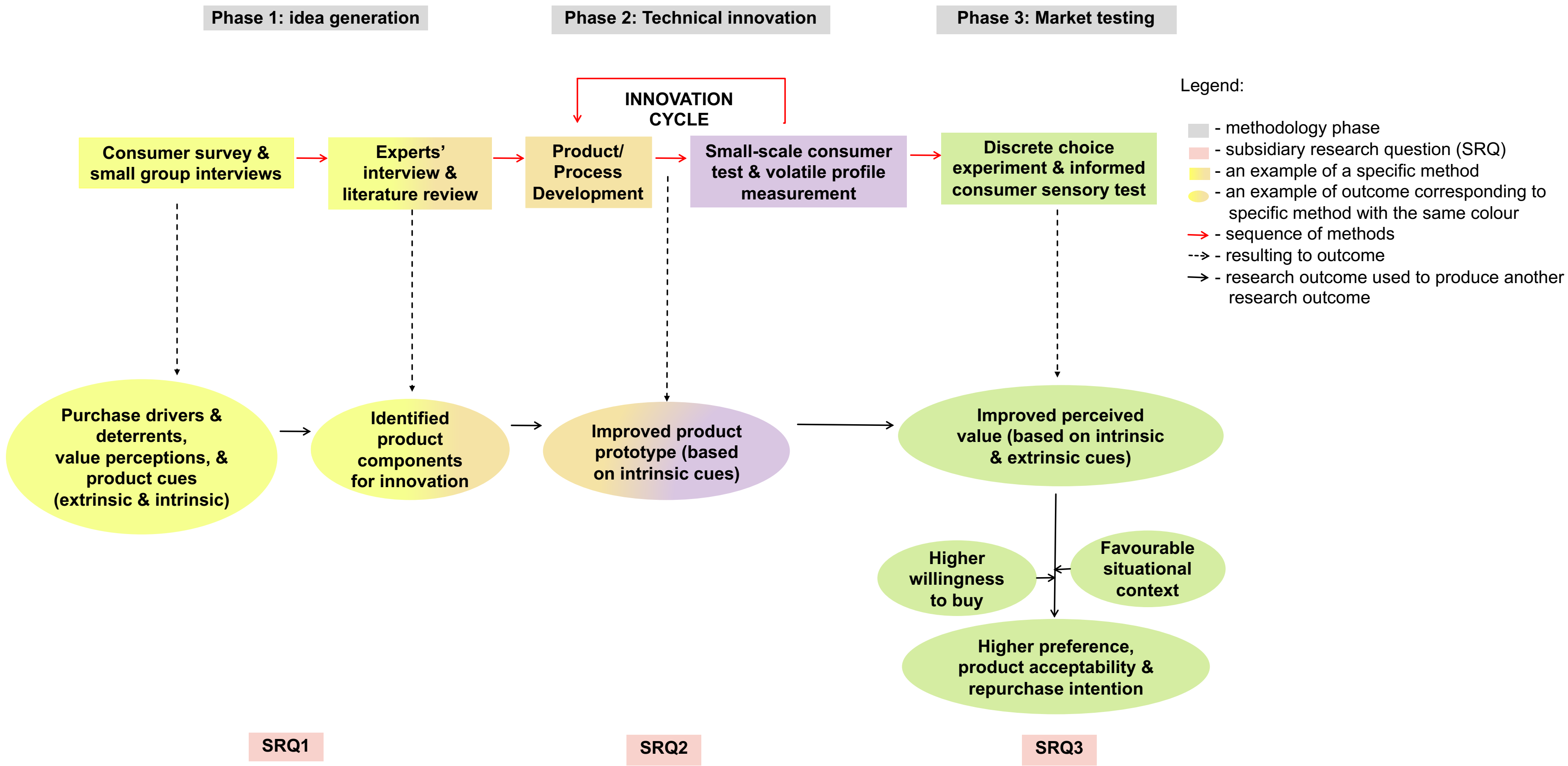

Fig. 2.8. Theoretical framework development for PVI model for FCF innovation.

The following SRQs were formulated and addressed in the thesis:

SRQ1: *Can consumer response information derived from the idea generation phase of the PVI model be used to guide the innovation of FCFs with improved perceived value?*

SRQ2: Can industry-appropriate postharvest techniques and a research tool that combines the subjective and objective measurements improve the perceived value of FCW in the technical innovation phase of the model?

SRQ3: Can simulation of purchase and consumption in the testing phase of the model, using a combination of discrete choice and informed consumer sensory test, effectively assess the improvement of the perceived value of developed FCW formats?

The application of mixed research methods in the implementation of the PVI model would be appropriate in order to address each of the SRQs. Quantitative methods such as consumer surveys (Phase 1 of Fig. 2.8), product acceptability tests and volatile measurements (Phase 2 of Fig. 2.8), choice experiments and consumer sensory testing (Phase 3 of Fig. 2.8) and appropriate statistical analysis are proposed. Qualitative methods such as in-depth interviews with individual or mini groups were also proposed in order to understand consumer perceptions, and product attributes that mostly influence purchase and repeat purchase (Phase 1 of Fig. 2.8). The sequence of the research methodologies is graphically shown in Fig. 2.8.

The effectiveness of the PVI model in producing FCFs with improved perceived value would be validated by addressing each of the SRQs. Addressing the SRQ of each phase would provide an input that is useful to the next phase, which continues until the last phase. SRQ 1 would be addressed by utilising the important information that mostly influence the perceived value of the end-users identified in Phase 1 (Fig. 2.8) to guide the technical innovation in Phase 2 (Fig. 2.8). Additionally, the inputs in Phase 1, particularly the important extrinsic cues, would be useful in the development of the FCW formats for the market testing in Phase 3 (Fig. 2.8).

SRQ2 would be addressed by employing the selected postharvest processing techniques, and testing using a combination of a small-scale consumer test and volatile measurements, in order to derive the most acceptable FCF prototypes for Phase 2 (Fig. 2.8). One postharvest technique worthy of investigation was MAP. This is widely used as a postharvest packaging technique in the food industry to maintain the quality of fresh and FCPs (Zhang et al., 2015). This technology is desirable for industrial applications because it is inexpensive, easily applicable to, and compatible with a wide range of production and packaging machinery (Spencer, 2005). Another application to be examined was the effects of the chemical-based methods of post-cut sanitation on the quality of the FCFs. These methods are the most common practice and do not require high capital equipment costs. In addition, the current published data suggest that none of the chemical-based sanitising agents can alone guarantee the microbiological quality of FCFs without compromising their sensory quality (De Corato, 2019). Research was therefore required to examine the effects of removing the post-cut sanitation wash spray step in the processing line on the resultant sensory quality of the FCFs. The use of fresh, uncrushed or ready-to-eat herbs, naturally containing essential oils was also selected as a cue to test for improved PV. Herbs are usually utilised as garnish for enhancing visual appeal, freshness and pleasant flavours. Their effects on the extension of the sensory shelf-life of commercially produced FCFs, however, are yet to be proven. Research to determine the effects of adding herbs on the quality and acceptability of FCFs, was therefore undertaken.

In order to test the effectiveness of each selected postharvest technique application to the improved sensory cues, combined subjective and objective measurements were proposed. The cut-off point shelf-life estimation method in Section 2.3.2.2 allows for utilising trained panellists in order to carry out the calibration of instrumental analysis to measure volatile changes. For instance, trained panellists could parallel the GC-MS-O analysis in order to identify the OAC of fresh and stored FCFs. The identified volatile compounds could then be utilised as markers of freshness or storage in order to assess the acceptability of the FCFs subjected to different postharvest techniques. Rapid monitoring of the volatile profile variations could be carried out using the PTR-MS. The PTR-MS allows for faster evaluation of whether the postharvest technique applied to maintain or improve sensory quality is effective or not. The volatile data could then be correlated to the flavour and overall liking scores of the consumer panellists in order to more efficiently understand product acceptability.

The existing in-house panellists of the FC industry partner are able to act as the consumer panellists to perform the consumer sensory testing at the end of every product development or IC. These panellists are useful for efficiently exploring acceptability of product prototypes and in identifying potential rework issues (dos Santos Garruti et al., 2012). Moreover, they may also assist in selecting samples that should be evaluated in real conditions tests. The consumer testing with in-house panellists involves identifying the sensory characteristics that need improvement, determining whether the prototype is different from the current one and finally confirming that the prototype is better than the existing one (dos Santos Garruti et al., 2012). These activities may continue until product prototypes are narrowed down to a manageable subset. With this approach the effects of the postharvest techniques on the sensory quality and shelf-life of FCFs can be determined using combined objective and subjective measurements.

Lastly, SRQ3 could be addressed by carrying out a combined DCE and informed consumer sensory testing to determine improvement and deviation of the perceived value of the developed FCF formats. These formats would be developed from improved intrinsic cues of the FCF prototypes derived from the ICs in Fig. 2.8, and combined with extrinsic cues previously identified in Phase 1 (Fig. 2.8). These testing techniques could be used to simulate purchase and consumption. Various studies have used the combined purchase and consumption simulation test. However, the literature on using this method for FCFs is scarce and would contribute to the consumer and sensory science literature. More importantly, this research is necessary in order to test the effectiveness of FCF innovation prior to product launch in the market. Consequently, the outputs of Phase 3 (Fig. 2.8) were to prove the effectiveness of the PVI model in delivering FCFs with improved perceived value.

Chapter 3 PVI Phase 1 Implementation: Idea generation

This addresses the research question formulated in Chapter 2: *Can consumer information derived from the idea generation phase of the PV approach be used to produce user-oriented FCFs?* It presents the first phase of the PV innovation model for FCFs as shown in Fig. 3.1. Phase 1 refers to identifying the value perceptions and related product cues for buying FCFs with FCW as the product in focus. Moreover, this phase also determines reasons for non-buying of FCFs, in order to address concerns in the current FCW format and improve the product. This information was necessary to direct the technical innovation of new FCW formats implemented in Chapter 4 which became the actual FCW products used for consumer evaluation in Chapter 5.

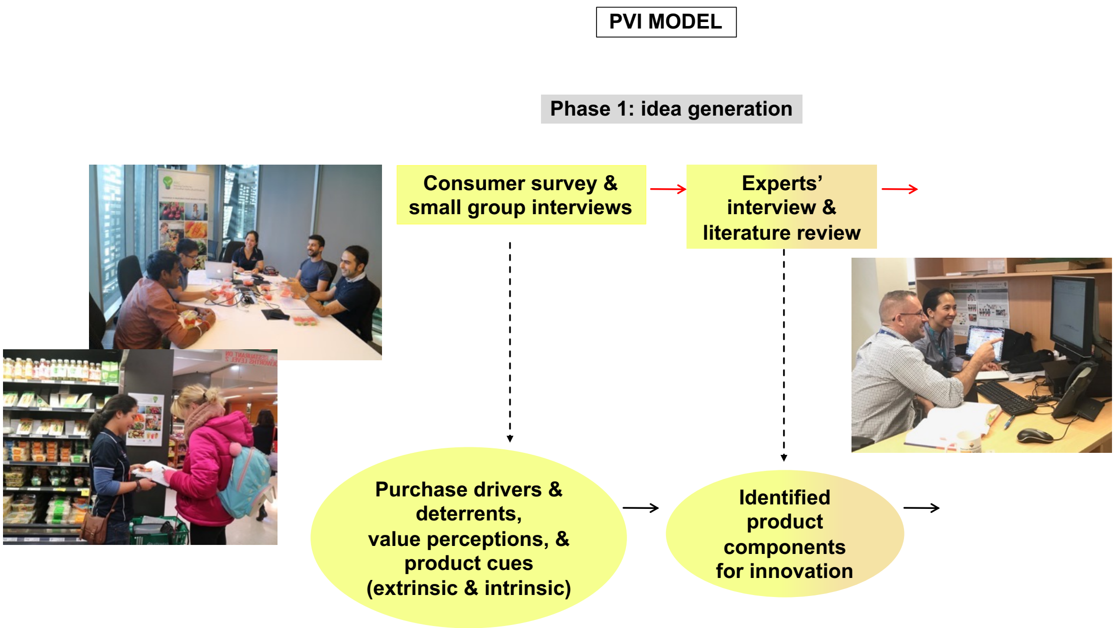

Fig. 3.1. Idea generation phase (Phase 1) of the PVI model.

Note: Photo reproduction with signed consent from the participants.

3.1 Introduction

Understanding the perceived value end-users have for the current offering of FCFs, and identifying related product cues, is necessary in order to direct future innovation. In the PVI model, this is the idea generation phase required to be implemented in order to guide the delivery of consumer-effective or user-oriented FCFs. FCFs were originally developed to offer consumers healthy and fresh fruits with greater convenience (Nicola and Fontana, 2014). The FCF product category combines the attributes desired in a modern diet such as healthiness, freshness and naturalness (Rocha and Morais, 2007). The FC industry however may expect the end-users to readily perceive these FCF benefits. However, perceptions of end-users for what constitutes quality varies between countries, regions, and individuals. Perceptions can also be affected by culture, experience, and personal preferences (Watkins and Ekman, 2005). Additionally, their perceptions of food innovation is contextual and thus, vary with location and product types available in the market (Winger and Wall, 2006).

Studies on perceptions and preferences for FCFs and similar products are limited (Baselice et al., 2017; Nassivera and Sillani, 2015; Pilone et al., 2017; Ragaert et al., 2004; Stranieri and Baldi, 2017; Vidal et al., 2013). Moreover, a number of published contributions focused more on FCVs such as FC vegetable salads, carrots, lettuce and beans. Since 2004 to date, only two studies have explored the perceptions and preferences of the end-users for FCFs. Both studies focused on FC rockmelon and were carried out with residents in the US (Mayen et al., 2007; Wilson et al., 2018). In addition, both studies only elicited response from the current end-users of the product. Given these considerations, an investigation on the perceptions and preferences of both the current and the potential end-users of FCFs in Australia was needed.

The study therefore aimed to determine the perceive value of the current and potential end-users for FCFs and related cues influencing purchase, in order to use this information to produce user-oriented FCFs with FCW as the model test sample. Two studies were conducted to implement Phase 1 of the PVI model. The first study was for identifying factors influencing purchase and non-purchase of the general FCFs (See Appendix 3.1 for the existing format of FCFs at the time of the research). The second study was for determining the value perceptions and related cues influencing the purchase and consumption of FCW as the test product for the PVI model. The results of each study were then linked to product components that could be changed and improved through the guidance of technical experts and literature reviews. The following experimental steps were carried out in each of the studies (Fig. 3.2). The details of each step are described in the subsections of Section 3.2.1 and 3.2.2.

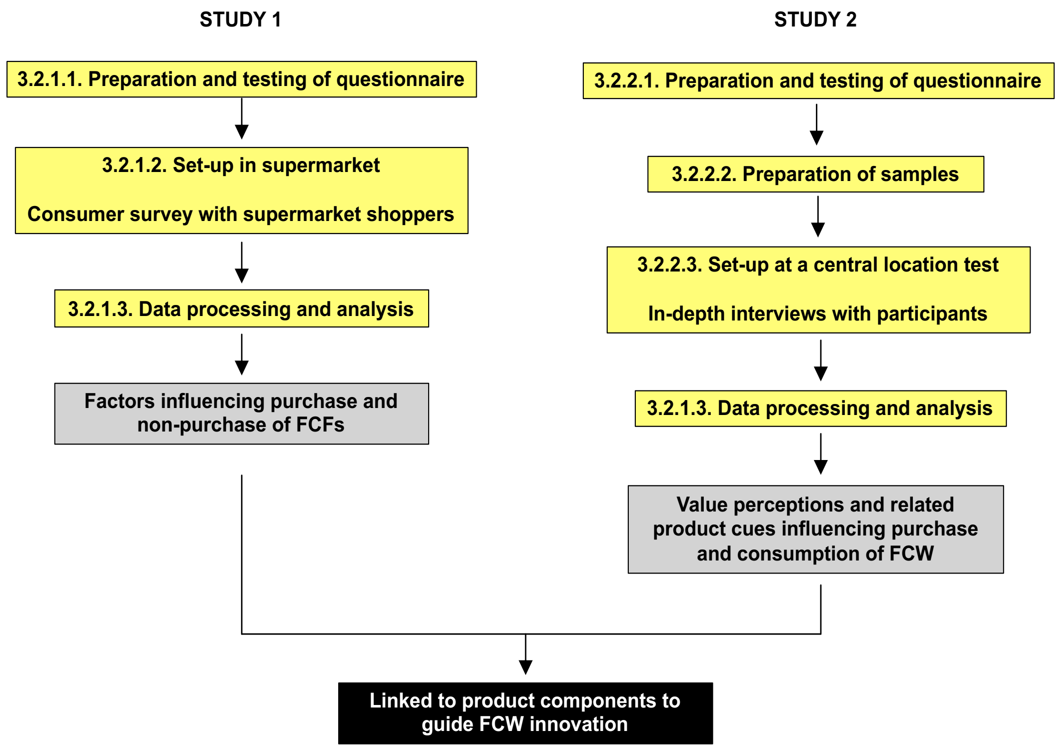

Fig. 3.2. Implementation steps and expected outcomes for Phase 1 of the PV innovation model.

3.2 Methodology

3.2.1 Intercept-administered survey for perceptions and preferences using BWS

3.2.1.1 Preparation and testing of the questionnaire

The survey questionnaire was prepared by formulating questions relevant to purchase and non-purchase behaviour of participants for the existing FCFs offering sold in supermarkets. Consequently, two sets of questionnaires were prepared: one for the current end-users of the FCFs and the other, was for the non-users. The questionnaires were organised in two parts and are reproduced in Appendices 3.2 and 3.3 for reference.

Each set of the questionnaires was divided into two parts and were completed in five to seven minutes. The first part included questions that are relevant to purchase or non-purchase of the end-users and non-users, respectively. This part also included the BWS scaling choice sets where the respondents were asked to choose the most and least important factors in buying FCFs for the end-users, and non-buying for the non-users. The second part-included questions pertaining to the socio-demographic information of the respondents.

A test run of the questionnaires was undertaken prior to conducting the survey in stores in order to determine the time required to complete the questionnaire. For this test run, 10 people were invited to participate. They were similar to the survey participants and would normally shop in the supermarkets for their food.

3.2.1.2 Experimental set-up in the supermarket

The intercept-administered consumer survey was conducted in four supermarkets at the central business district metropolitan Sydney, Australia in June 2017. A booth was set-up close to where FCFs were displayed to perform the consumer survey (Appendix 3.4). Random supermarket shoppers in the vicinity of the experimental booth set-up were approached and invited to participate in the consumer survey. When they agreed to participate, an information pamphlet about the research objectives and the detailed instructions of the experiments was given, and a signed consent was obtained. Human Ethics approval was granted by the University of Tasmania (Approval number H0015933) prior to conducting the consumer survey.

A total of 171 (96 = current end-users and 75 = non-users) willing consumer participants joined the intercept-administered survey. The participants were of 56 % females and 44 % males, with age ranges of 18 - 30 years (61 %), 31 - 40 (17 %), 41 - 50 (9 %), 51 - 60 (6 %) and > 60 (7 %). The cultural background was 36 % Asian, 30 % Australian, 20 % European, 2 % Middle Eastern, 1 % African, 6 % Latin American and 4 % American.

Willing participants were first asked if they buy and eat FCFs in the supermarket and were then given the appropriate survey questionnaire. During the intercept-survey each participant was verbally guided through the questionnaire. For the current end-users of FCFs, questions related to familiarity of the product and frequency of purchase were asked. For every purchase of FCFs, questions relating to consumption, and factors influencing repeat purchase after consumption, were also asked of these participants. Additionally, they were asked about their suggestions for improving the current FCF offering. Current non-users of FCFs, on the other hand, were asked if there would be any likelihood for them to buy these products in the future. They were also asked about their familiarity with FCFs and suggestions for improvement of the current offering. For the BWS choice sets, the participants were asked to choose the most important and least important factors influencing their purchase of FCFs for the end-users. In contrast, non-users were asked to select the most important and least important factors influencing their non-purchase of FCFs. All participants completed 13 choice sets.

3.2.1.3 Data collection, processing and analysis

3.2.1.3.1 Purchase and consumption data

Purchase and consumption behaviour of the current end-users and the perceptions of non-users of FCFs were collected then encoded and processed in Excel® (Microsoft version 16.33). Frequency and descriptive analysis were carried out and later summarised into figures and summarised in tables.

3.2.1.3.2 BWS data

The BWS data were collected based on factors that motivated the current end-users or deterred the non-users to purchase the FCFs. The list of determinants and deterrents (Tables 3.1 and 3.2) of purchase were selected based on the common product cues influencing purchase of FCFs and similar products from the literature review summarised in Table 2.6 in Chapter 2. The BWS data were processed and analysed based on the experimental design and protocol of Lockshin et al. (2015). A balanced incomplete block design (BIBD) design was applied in order to allocate the factors influencing purchase and non-purchase of FCFs (Tables 3.1 and 3.2). Thirteen (13) choice sets were prepared for each participant to respond (Table 3.2). Each factor appeared four (4) times across all choice sets and appears once with each other. The experimental design is presented in Table 3.3. Examples of the choice sets are presented in Fig. 3.3. These examples represent choice set number 10 in Tables 3.1 and 3.2, and contains Factors 10, 11, 13 and 6 for both purchase and non-purchase factors. In each choice set, the participant was asked to choose the most and least important factors that influence purchase or non-purchase while considering possible purchase of FCFs in a retail store.

Table 3.1. Possible factors influencing purchase of FCFs.

Assigned number	Factors	Reference
1	Fruits look fresh	Stranieri and Baldi (2017), Baselice et al. (2017); Dinnella et al. (2014)
2	Juice at the bottom of the package	Mayen et al. (2007)
3	Shape of fruit pieces	Baker et al. (2015)
4	Packaging size	Castro et al. (2018)
5	Packaging shape	Castro et al. (2018)
6	Information on the label	Alongi et al. (2018), Castro et al. (2018), Nousiainen et al. (2016)
7	The place I buy is close to where I am	Kyureghian et al. (2013), Rose and Richards (2004)
8	Product's location in store	Castro et al. (2018)
9	Promotional display in store	Mao (2016), van Donselaar et al. (2016)
10	Price	Chinnici et al. (2019), De Souza et al. (2007), Massaglia et al. (2019), Pilone et al. (2017)
11	Contains my favourite fruits	Chinnici et al. (2019), De Souza et al. (2007), Massaglia et al. (2019), Pilone et al. (2017)
12	Doesn't go off easily even when consumed later in the day	Manzocco et al. (2013)
13	Use-by date	Alongi et al. (2018), Stranieri and Baldi (2017),

Table 3.2. Possible factors influencing non-purchase of FCFs.

Assigned Number	Factors	Reference
1	Doesn't look fresh	Baselice et al. (2017) Dinnella et al. (2014)
2	Shorter shelf-life	Alongi et al. (2018), Stranieri and Baldi (2017)
3	Range not appealing	Chinnici et al. (2019), De Souza et al. (2007), Massaglia et al. (2019), Pilone et al. (2017)
4	Doesn't contain my favourite fruits	Chinnici et al. (2019), De Souza et al. (2007), Massaglia et al. (2019), Pilone et al. (2017)
5	Unnecessary packaging	Venter et al. (2011)
6	Portion size not right for me	Gumber and Rana (2019)
7	Too expensive	Chinnici et al. (2019), De Souza et al. (2007), Massaglia et al. (2019), Pilone et al. (2017)
8	Not my habit	Gumber and Rana (2019)
9	Prefers to cut fruit myself	Gumber and Rana (2019)
10	Don't trust the quality	Zhang et al. (2018)
11	Just haven't tried it	Gumber and Rana (2019)
12	Not readily available	Kyureghian et al. (2013), Rose and Richards (2004)
13	Store where to buy is far from my location	Kyureghian et al. (2013), Rose and Richards (2004)

Table 3.3. Balanced incomplete block designs for 13 purchase/non-purchase factors of FCFs.

Choice set number	Factors			
1	1	2	4	10
2	2	3	5	11
3	3	4	6	12
4	4	5	7	13
5	5	6	8	1
6	6	7	9	2
7	7	8	10	3
8	8	9	11	4
9	9	10	12	5
10	10	11	13	6
11	11	12	1	7
12	12	13	2	8
13	13	1	3	9

Source: Lockshin et al. (2015)

MOST		LEAST
☐	Price	☐
☐	Contains my favourite fresh-cut fruits	☐
☐	Use-by date	☐
☐	Information on the label	☐

a) For current end-users

MOST		LEAST
☐	Don't trust the quality	☐
☐	Just haven't tried it	☐
☐	Store where to buy is far from my location	☐
☐	Portion size not right for me	☐

b) For current non-users

Fig. 3.3. Examples of BWS choice sets of FCF consumer survey.

BWS data were processed and analysed based on the protocol of Lockshin et al. (2015). All data were encoded and processed in Excel® (Microsoft version 16.33). The data were processed in a matrix by transforming the factor numbers in the choice sets to the original factor numbers in Tables 3.1 and 3.2. For each choice set, the factor selected as either the most or least important was counted as one. After data transformation, the total scores of all participants for each factor, when it was selected as most or least important, were obtained. For each factor, the total score for when it was selected as the most important factor (best) was subtracted from the total score for when it was chosen as the least one (worst). For standard ratio expression, the square root of the best and worst scores ratio (B/W) for each factor was computed. The square root of B/W for all factors was scaled by the highest B/W score in order to normalise the most important factor as 100 %. All factors were ranked from most to least important based on the percentage standard ratio.

3.2.2 Study on FCW perceptions and cues using in-depth interviews

A combination of mini-group and individual in-depth interviews were conducted in order to understand the perceptions and product-related cues for FCW (Appendix 3.5). The in-depth interviews were carried out among 16 individuals (8 current end-users and 8 non-users of FCW). Some participants were invited from the previous consumer survey while others were invited by colleagues of previous participants. When they agreed to participate, an information sheet about the research objectives, and the detailed instructions of the interview was given, and a signed consent was obtained. Human Ethics approval was granted by the University of Tasmania as part of Approval number H0015933 prior to conducting the in-depth interviews.

3.2.2.1 Preparation and testing of the interview guide

Two semi-structured interview guides (Tables 3.4 and 3.5) were developed according to established guidelines (Deliza et al., 2003). The interview guides consisted of a checklist of topics related to either current end-users (Table 3.4) or non-users (Table 3.5) of FCW purchase. The interview guides were pretested among research university colleagues and in-house participants of the industry partner. Revisions were made according to their comments. For parts 4 and 5, current formats of FCW were presented to the participants to elicit cue perceptions combined with Laddering technique (Reynolds and Gutman, 1988) and explore the links of the cue-attribute-quality perceptions. The interviews took between 30 and 60 minutes.

3.2.2.2 Experimental set-up

Willing participants were invited to go to the interview location in order to participate in the in-depth interviews. The participants were engaged during the discussion using the interview guides in either Tables 3.4 and 3.5. The session lasted approximately 90 and 60 minutes for current FCW end-user and non-user, respectively. The interviews were video and audio recorded. The participants were informed about the recording beforehand. The moderator started the session by introducing herself and informed participants on the usage of their opinions, beliefs and suggestions for the improvement of the current FCW offering. The participants were also asked to briefly introduce themselves and the discussion started (Tables 3.4 and 3.5). For the proposed FCW formats, actual prototypes were made and shown to the participants for their critique and improvement suggestions.

Table 3.4. Interview guide for in-depth interviews among current end-users of FCW.

Part 1: Introduction
Welcome and introduce self
Explain research objectives
Explain how discussion works
Explain equipment (camera recorder)
Assure confidentiality
Part 2: Regarding opinions and attitudes towards FCW
Can you describe to the group what you think about fresh-cut watermelon?
What is your overall impression about this product?
What do you like most about it? (What do you dislike most about it?)
How often do you buy this product?
When do you normally consume this product?
What benefits do you get when you consume fresh-cut watermelon?
In your mind, what do you feel when you eat fresh-cut watermelon?
Part 3: Regarding previous buying experience of FCW
When did you buy it last? Can you recall why you bought FCW at that time? Are there any other reason why you bought it last time?
Do you normally buy FCW? If they are not available in the shops where you normally buy it, will you look for it in other shops?
Where did you buy it last? Why did you buy it there?
In those shops where you bought it, did you find its location easy to find? Any suggestions where in the shop you would want to see it?
Can you remember what you paid for when you bought it? Do you think it is worth the value for your money? Why or why not?
Part 4: Regarding FCW cues and importance in purchase decision
What did you look for in the FCW when you bought it?
How did you evaluate quality? How did you know if it was a quality FCW?
How did you evaluate other aspects of FCW that you looked for?
Why is each attribute important to you when buying the FCW?
Part 5: Regarding current formats of FCW in the market
Can you tell me what sorts or formats of FCW are available in the market?
Are you happy (satisfied) with these current formats of FCW in the market?
Are you getting the quality FCW that you want? Why or why not?
Do you have any suggestions for the improvement of this format? What improvements can you suggest?
Given that the current price is AU$ 3.50, how much more are you willing to pay for the suggestions you gave for this product?

Table 3.5. Interview guide for in-depth interviews among non-users of FCW.

Part 1: Introduction	
	Welcome and introduce self
	Explain research objectives
	Explain how discussion works
	Explain equipment (camera recorder)
	Assure confidentiality
Part 2: Regarding reasons for buying and consuming whole watermelon instead of FCW	
	May I know your reasons for not buying FCW?
	What mostly influence your decision to purchase whole watermelon?
	When do you want to use or consume whole watermelon instead of FCW?
	What do you look for when deciding to buy whole watermelon?
	What for you is a quality watermelon? How do you know when you see a quality one?
	How do you evaluate quality and other aspects of the fruit that you look for?
	Why is each attribute important to you when buying the fruit?
	When whole watermelon is prepared in cut forms and sold in shops (show pictures of FCW), will you buy it? Why or why not?
Part 3: Regarding current FCW formats	
	Can you describe to me what you see in the FCW format?
	What do you like/ dislike about it? Would you buy this FCW format?
	Do you have any suggestions for the improvement of this format? What improvements can you suggest?
	Given that the current price is AU$ 3.50, how much more are you willing to pay for the suggestions you gave for this product?

3.2.2.3 Data processing and analysis

The interview transcripts were approved for inclusion by all participants. A qualitative thematic analysis was undertaken using NVIVO 12 (QSR International, Australia). Data were analysed based on the context of the question and specificity of the responses. Word frequency analysis was also run in order to determine the most common and important responses of the participants and presented as word clouds. Statistical analysis was not performed due to the qualitative nature of the study (Jervis and Drake, 2014). Data provided in interviews were validated by cross-referencing with other interview statements. Participants were also contacted, as needed, for a follow-up clarification on the transcripts by mobile phone or email.

3.2.3 Linking of product related consumer information to product components

The product-related consumer information from the survey and interviews were linked to product components through the guidance of experts and literature review.

Preliminary trials of objective and subjective measurements, such as volatile analysis and sensory testing, were also conducted to verify the relationships of cues and product components. The results of linkage were analysed based on the means-end-chain perspective of Grunert and van Trijp (2014b).

3.3. Results

3.3.1 Survey results

3.3.1.1 Familiarity to FCFs and similar products

The majority of participants were familiar with FCFs and similar products (Fig. 3.4). More than 50 % of the current end-users were very familiar with the product category. In comparison, 40 % of the non-users were also very familiar with it. Only 10 % of the non-users and 1% of the current end-users were accounted as less or not familiar at all. The rest of the participants, regardless of usage, fell between the slightly to quite level of familiarity with FCFs and similar products (Fig. 3.4).

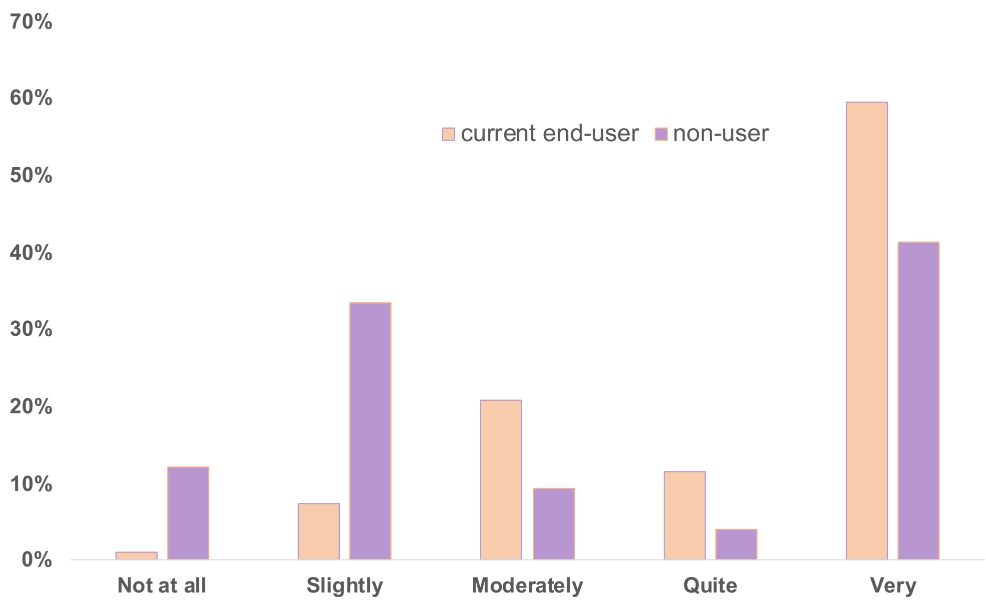

Fig. 3.4. Familiarity of the current end-users and non-users to FCFs and similar products.

Conditions: Results were computed based on the current end-users (n = 96) and non-users (n = 75) of the current commercial offerings.

3.3.1.2 Purchase and consumption of the current end-users of FCFs

The frequency of purchase among the current end-users of FCFs was low (Fig. 3.5). Almost half of these participants only purchased FCFs one to three times a month and less than 10 % only bought every day or more than three times a week. The rest of the current end-users of FCFs either bought FCFs one to three times weekly or fortnightly (Fig. 3.5). After each purchase, about 90% of the participants would consume the product immediately while the rest would consume it not later than 48 hours (Fig. 3.6).

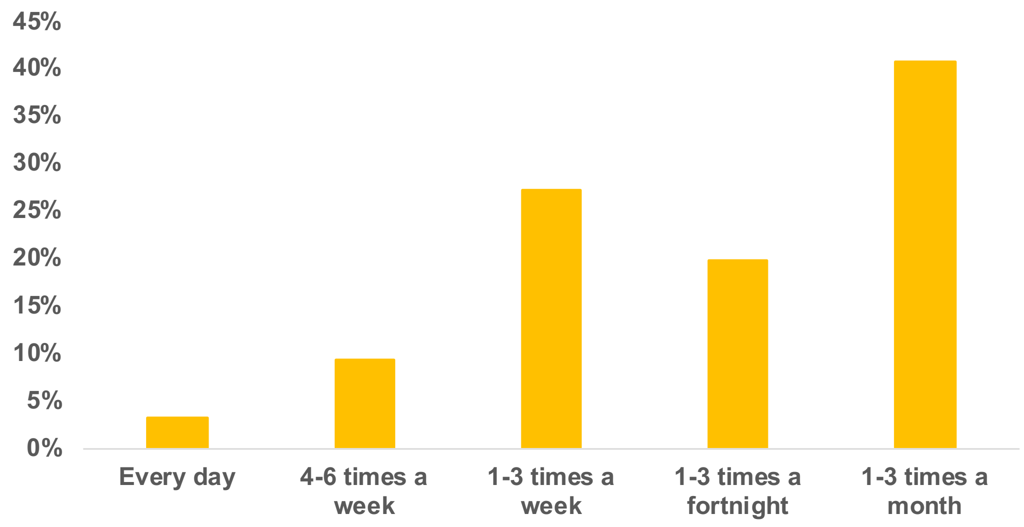

Fig. 3.5. Frequency of purchase among end-users of the current FCF offerings.

Conditions: Results were computed based on the users (n = 96) of the current commercial offerings.

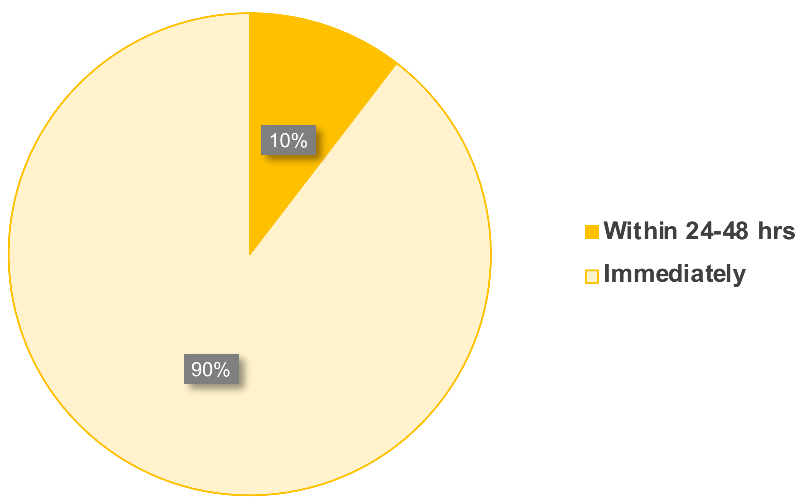

Fig. 3.6. Consumption of FCW after purchase.

Conditions: Results were computed based on the number of end-users (n= 96) of the current FCF offerings.

3.3.1.3 Factors influencing purchase of FCFs

A number of factors influencing purchase of FCFs were accounted in Fig. 3.7. The most important ones referred to the main product itself such as fresh appearance, presence of favourite FCF types and freshness of the product throughout the day. Price and use by date (UBD) information came next as very important factors affecting the purchase of the current end-users for FCFs. Promotional display in the store and the proximity of the store to where they buy the FCFs were also considered by some as influencing their purchase. Other factors that were not as important, included other information on the label, packaging size and shape, shape of the fruit pieces, juice sitting at the bottom of the package and the location of FCFs in the store (Fig. 3.7).

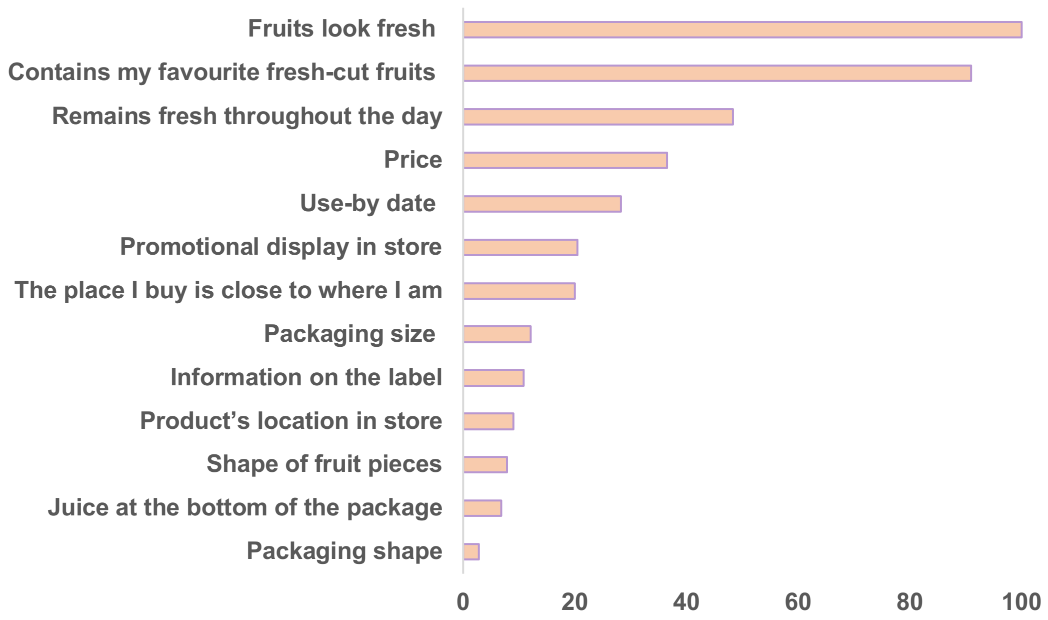

Fig. 3.7. Factors influencing purchase of FCFs.

Conditions: Computation is based on the standard ratio scale of BWS from the end-users (n= 96) of the current FCF offerings.

3.3.1.4 Factors influencing repeat purchase of FCFs

After consumption, factors relating to the sensory characteristics of the FCFs influenced the repeat purchase intent of the current end-users (Fig. 3.8). Taste and flavour accounted for the most significant factors that would determine their repeat purchase and were followed by the presence of spoon or fork included in the FCF pack. Crunchiness of the fruit pieces was as important as was the smell of the pack upon opening. The ease of opening the packaging was not as important as the sensory experience with the FCFs (Fig. 3.8).

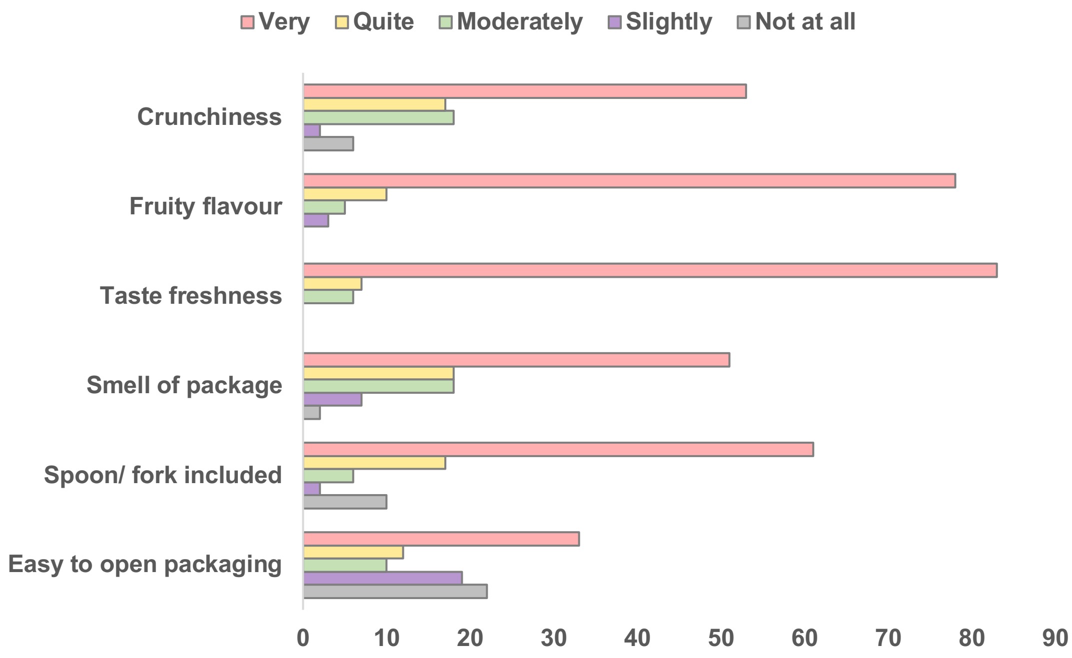

Fig. 3.8. Factors influencing repeat purchase of FCF offering.

Conditions: Results were computed based on the number of end-users (n= 96) of the current FCF offerings.

3.3.1.5 Factors influencing non-purchase of FCFs

Several factors influenced the non-purchase of FCFs (Fig. 3.9). Sixty-eight (68 %) per cent of the non-user participants had not tried FCFs. They mostly preferred to cut their own fruit rather than have others prepare it for them as FCFs. The fresh appearance of the products in the retail shelves significantly affected their non-purchase. Those who had past experience with the FCFs also said that the product did not look fresh to them and they did not trust the product quality. The price of the current FCF offering also significantly influenced non-purchase. It was considered rather expensive. Moreover, for these participants, FCFs had shorter shelf-life in comparison to the whole fruits they bought in the market and the portion size was not right for them. Thus, the FCF alternative was often selected. In addition, the product range was not appealing to them as it did not contain their favourite fruit. The single use-plastic packaging to contain the FCFs also turned off the non-users from buying. The accessibility of FCFs and the distance of their location from the store were the least important factors influencing their non-purchase (Fig. 3.9).

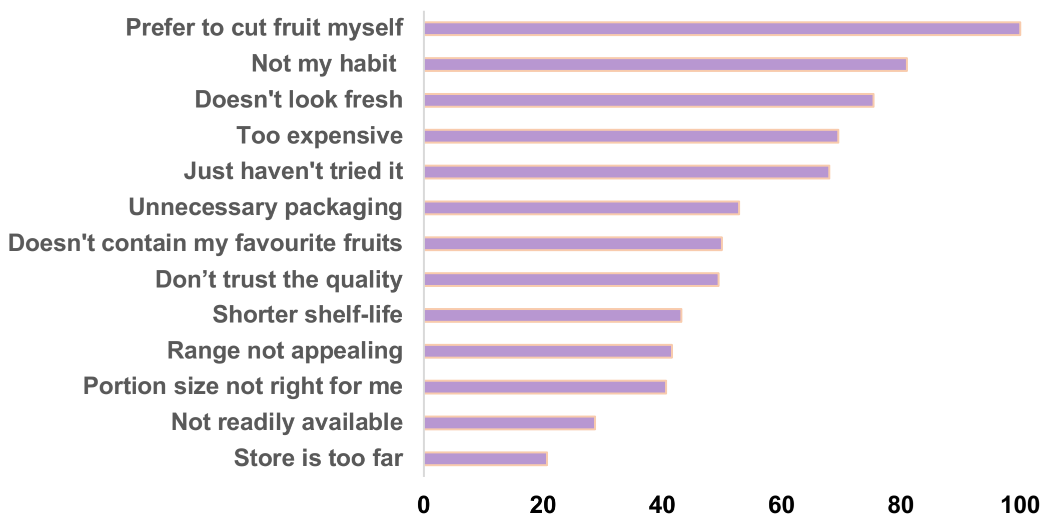

Fig. 3.9. Factors influencing non-purchase of FCFs.

Note: Computation is based on the standard ratio scale from non-users (n= 75) of the current FCF offerings.

3.3.1.6 Suggestions for improving the current FCF offering

Suggestions for improving the current FCF offering were provided by both the current end-users and non-users. The improvement suggestions were classified according to the level of product design improvement. Higher regard was given to the improvement of the core product, followed by the actual product which included the packaging and information on it. Suggestions for improving the augmented product design were also provided (Fig. 3.10). Current end-users were keener on improving the actual product design than the non-users, especially on improving the packaging and presentation of FCFs. Non-users, on the other hand, were more concerned with improving the main product and accessibility of the FCFs than the current end-users.

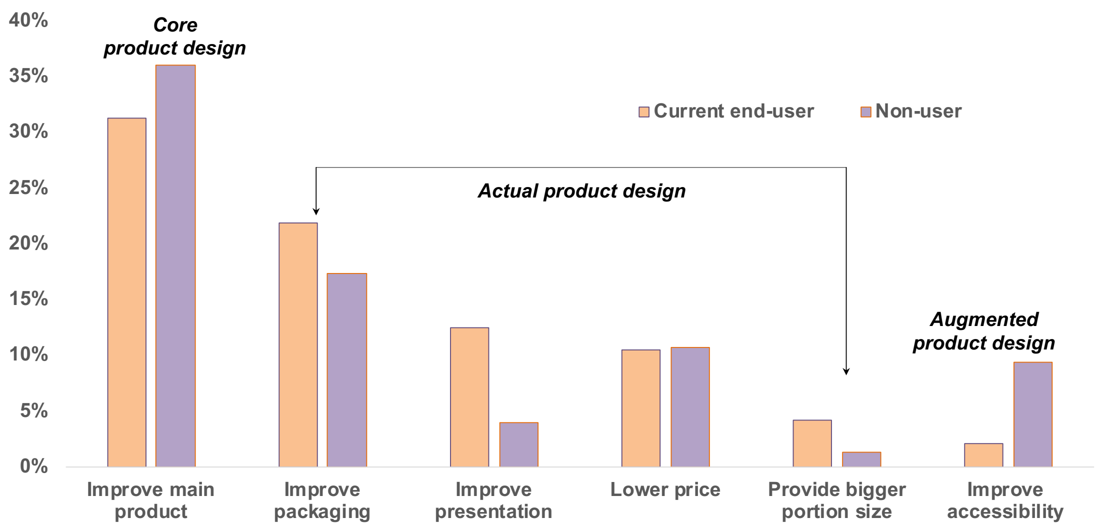

Fig. 3.10. General improvement suggestions for the current FCFs.

Note: Core product refers to the main edible product portion. Actual product refers to the packaged core product as it appears in the retail market. Augmented product refers to how the actual product is delivered to consumers (Armstrong and Kotler, 2009).

The details of improvement suggestions were summarised and ranked in Table 3.6. For improving the main product, maintaining freshness was considered paramount. Suggestions, especially for mixed fruit or fruit salad, were to keep the fruit pieces intact and to separate hard from soft fruits or separate juicy from non-juicy fruits. Not including watermelon in the fruit mix was recommended in order to keep the product longer and lower the amount of juice at the bottom of the package. Additional variety and assortment of fruit for fruit salads were also proposed by adding more berries and exotic fruits such as banana and citrus fruits. Moreover, yoghurts, nuts and mueslis were suggested to be added in the fruit mix. Providing a diverse range of FCFs was suggested, however, individual packing of these fruits was recommended. Single type FCFs were regarded as better products compared to fruit mix. Further suggestion included making an icy cold FCFs during summertime (Table 3.6).

Suggestions to improve the actual product design were also provided (Table 3.6). A focus on packaging improvement with the use of biodegradable plastics packaging and resealable lids were suggested. Improvement of packaging to enhance convenience was also suggested, which included addition of wet tissues and placing a more stable spork outside of the package. Making the packaging more appealing was a suggestion. According to the participants, this could be done by using artistic packaging design or matching the shape of the fruit pieces with the packaging shape. Most of the cut fruit pieces were in cubes, and hence a square packaging was suggested. Additionally, a shorter and broader type of packaging was suggested for single type of FCFs. For packaging labels, additional information was recommended such as the inclusion of safety and quality certifications, nutrition facts, types of fruits and other ingredients. The non-usage of artificial preservatives was also emphasised (Table 3.6).

Suggestions on the improvement of the actual product design of the FCF were further classified into improvement of the product presentation, price and portion sizes (Table 3.6). Maintaining fresh appearance of all cut fruits was highlighted in the suggested improvements for product presentation because the packaging used is transparent. Moreover, maintaining uniform bite-sizes and shapes of the fruit pieces and absence of seeds and peel of fruits was recommended. For fruit salad, an equal proportion of the cut fruits in the fruit mix was also recommended. Making the packaging label look more appealing was also suggested by the participants. For pricing, the price of FCFs in 200 g packs when the survey was conducted was AU$ 3.50. The participants suggested to lower this into AU$ 2.00 – 3.00 as the sources of the fruits were mostly local in Australia. For the portion sizes, the non-user participants also suggested to increase size for the single portion while some end-user participants suggested to decrease it (Table 3.6).

Table 3.6. Specific improvement suggestions for the current FCFs.

Specific suggestions	Rank
Improve main product	
Maintain freshness (fresh appearance, intact fruit pieces, low juice level at the bottom of the package)	1st
Provide assortment	2nd
Providing diverse FCF range but individually packed single-type of fruit	3rd
Add other ingredients such as yoghurt, muesli and nuts	4th
Make icy cold FCFs in summer	5th
Improve packaging	
Use environmentally-friendly packaging	1st
Put the spork outside and make sure is stable	2nd
Add the following on the label: nutritional facts, type of fruits, ingredients (no artificial preservatives) and origin of the fruits	3rd
Make packaging interesting and more appealing (dome-shaped lid for fruit salad; shorter and wider for single-type of fruit)	4th
Use resealable lids	5th
Use square packaging rather than cup	5th
Add wet tissue	5th
Add certification of safety and quality in the packaging label	5th
Improve presentation	
Provide nicely cut bite-size of the fruit	1st
Smaller cut size of watermelon	2nd
Uniform size and shape of fruit pieces	3rd
Equal proportion of the fruits	3rd
No seeds and no skin of the fruit	3rd
Make labelling more appealing	3rd
Lower price	
From existing AU$ 3.50 to 2.00 or 3.00 per 200g	N/A
Provide different portion sizes	
Provide bigger or smaller portion size of FCFs	N/A
Improve accessibility	
Cut fruit to order	1st
Make available in a salad bar	2nd
Place the FCFs near the counter	3rd

Some suggestions for the improvement of the augmented product design also recommended improving accessibility of the FCFs (Table 3.6). These included cutting the fruit as it is ordered, making the product category available in a salad bar inside the retail market and placing the existing FCFs near the counter (Table 3.6).

3.3.2 In-depth interview results

3.3.2.1 Watermelon perceptions

Several perceptions of watermelon benefits were derived from the in-depth interviews (Fig. 3.11). Most participants described watermelon in general, as rehydrating, juicy and refreshing especially in hot weather or summer.

> "I feel rehydrated straight away because it is so juicy and its refreshing in hot weather."
> "The watermelon is not really filling but it is something refreshing."
> "Watermelon is a bit juicy so it could be icy cold. I want watermelon in summer. I don't crave for watermelon when its winter."
> "It is the juiciness and the freshness that I like when it hot."
> "It is refreshing. In hot weather, it's one of the go-to's in the fridge."

Some perceived the fruit as having less vitamins, but more fibre and water, and hence they feel fuller and more satiated.

> "I don't think watermelon is packed with vitamins and I don't think it's a superfood but I think it has the fruit fibre."
> "Also because of the fibres, better for satiation… you feel fuller and its better for you."

One also experienced feeling good and healthy after eating watermelon.

> "I feel healthier after eating watermelon. Like, I feel so well or I feel so healthy!"
> "You don't feel its heavy and it is pretty healthy. It is nice to have it as a snack."
> ""I feel better, less guilty. Because that is probably the only few times when I eat fruit or when it is served in front of me. Because I don't usually buy the fruit itself and prepare for it. I don't usually do that ... so when I eat the fresh-cut fruit, I feel good and less guilty. Oh, I'm healthy today so it's a good feeling."

Watermelon was also perceived as generally sweet and juicy. One commented that these sensory characteristics, however varied with season.

> "I think it is a very variable fruit. Some fruits taste basically the same all the time. But watermelon really changes and when it is in season it tastes much better. In my experience if you buy watermelon early December, it doesn't taste as nice as when you buy it at the end of January. It is really after Christmas that it gets nicer and nicer, and this lasts until March. When I buy watermelon not within this season then it is not as sweet and juicy."

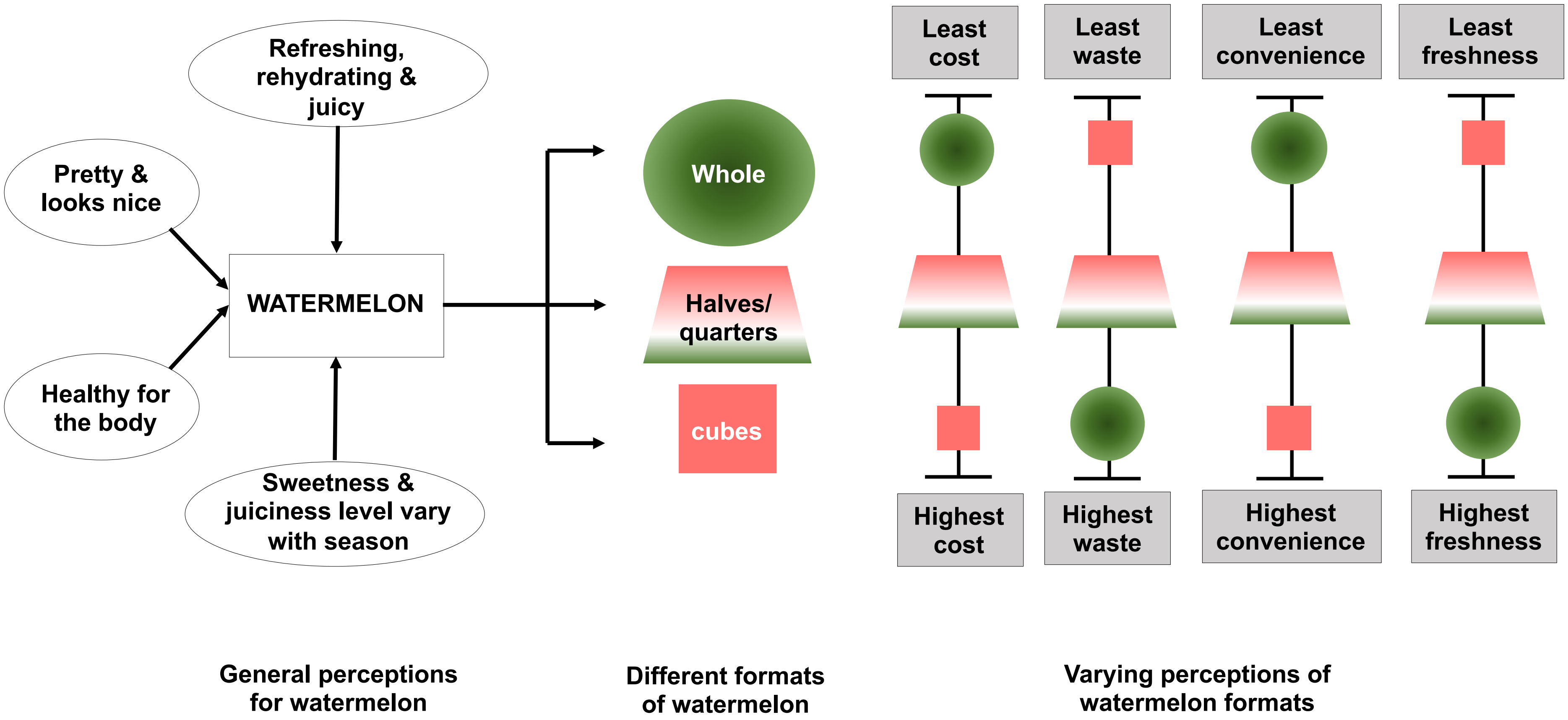

Fig. 3.11. Perception for different watermelon formats.

Derived from the in-depth interviews of mini-groups and individuals (n = 16 respondents).

Other sensory characteristics, like its colour and look, were described as pretty and nice. Watermelon added colour and increase the visual appeal of a fruit platter.

> "I buy it to add a bit of colour and bright in the platter of fruit."
> "It looks very pretty in a fruit platter, it looks nice."

Some also observed that the colour relates to the flavour and sweetness of the watermelon. The sweeter the watermelon is when the colour is deeper.

> "The pinker it is, the more flavour it would have and the sweeter it would be."

There were three different formats of watermelon described by the participants, which included the whole one, those cut in halves or quarters and those cut in cubes (Fig. 3.11). A variety of perceptions were expressed for these specific formats.

3.3.2.1.1 Whole fruit

The users of the whole fruit preferred to prepare and cut the fruit themselves because they have time and perceived it as freshest.

> "I just prefer to buy the whole thing and do it myself as I want to."
> "I like those in whole because I do have the time."

The non-users of the same format, however, described the whole one as inconvenient and too big to eat for a single portion.

> "Fruits like watermelon and pineapple are hard to prepare unlike apples that are easy to chop up."
> "I never bought a whole one because it's too hard to cut and I've got issues with my wrist."
> "I know how difficult it is to cut watermelon or even carry watermelon back home."
> ""It takes lots of time and messy to clean when you have to cut the whole fruit."

Some also commented that whole watermelon was more preferred for bigger size family and gatherings, and therefore, it would not suit people who are living alone.

> "A lot of people are living alone and sometime you just can't eat the whole watermelon."
> "I usually buy for my family. We are mostly four."

3.3.2.1.2 Cut in halves or quarters

Similar to the whole watermelon, those cut in halves or in quarters were usually bought when a number of people are around to eat together.

> "I usually buy half-watermelon and prefer to eat with other people to make it worthwhile consuming it."

Those cut in halves and quarters were preferred by some participants because it allowed them to check the visual quality of the flesh of the watermelon. One even said that it was her way of checking whether or not the watermelon was ripe and sweet.

> "I usually buy those ones in quarters or halves because then I can see when it's really ripe. I like it because they enable me to choose the best between not very tasty and sweet and tasty… so I like to choose the sweetest one. It helps me cut down the risk of choosing that one that's not nice."

The drawback of these formats, however, was the difficulty to find the size of the pieces that the consumer wants. Storage space was an issue for bigger portion sizes of those cut in halves and left-over portions of whole ones.

> "Sometimes I find it hard to find the size of the piece I want. I think the small size end up to be chosen quickly so I end up to buy whatever size is there and sometimes the pieces are very big and difficult to put in the fridge."

Apart from the storage concern, the left-over portion of whole and those fruit cut in halves and quarters also affects the taste.

> "If I have to buy the whole watermelon or those cut in bigger portions, I have to keep it in the fridge and after one day the taste has changed."

3.3.2.1.3 Cut in cubes

Fruit cut in cubes, referred to in this study as FCW, addresses concerns of both storage and changes in taste, which were critical factors in repurchasing of watermelon.

> "The FCW is good because you can eat it at one time. No need to keep it in the fridge. It is very easy to buy and eat."
>
> "I guess amongst all the cut fruit that I tried, I think the watermelon is probably the best in taste. The rest were too sour like pineapple or apple. Watermelon is really the best one."

FCW was described as convenient because it was packaged with only the edible portion of watermelon, and came with fork. Most participants commented that FCW took away the hassle of preparation. Moreover, FCW was perceived as an on-the-go fruit snack or meal replacement for people who are busy and those who live alone as the format provide the right portion size.

> "For me, FCW is very convenient. Because I don't have to cut the entire fruit by myself. I don't have to eat the whole lot all by myself. By buying the fresh cut one, you only get fruit and pay the same the same amount. And also, the convenience of cutting. I don't like cutting at all."
>
> "Preparing and eating watermelon requires hard work."
>
> "It is pre-packaged already. That one in transparent cups with watermelon slices, is a good thing for me because like other people who don't have time to prepare or convenience of preparing

watermelon. It would be so convenient if you can just grab it on your way to work or even go back home."
"I also like the pack one because I lack the time to cut and prepare. The FCW is so easy because you just grab and eat it in your room."
"My impression of those cut fruits in general is for people who are buying these products for their own lunch or for their own snack. I think it's a convenience food for people who are out."
"But these days, people are busy and they don't have time to cut watermelon, they have to buy the cut watermelon in cups."
"I would buy those in cups/ packs often instead. It is just easier. I would probably get the cubes one because I can just have it right there."
"I would go for the watermelon cubes because it already has the fork."
"Having one in a package and when you feel like eating it, that one like in a single serve is pretty good."

3.3.2.1.4 Contrasting perceptions of watermelon formats

Contrasting perceptions were expressed for the different formats of watermelon. These perceptions vary mainly in terms of their levels of convenience and freshness, their cost, as well as their price or waste (Fig. 3.11). The level of convenience was perceived to be directly proportional with pricing, but inversely proportional with freshness level, and preparation waste. Some comments from the participants who were non-users of FCW said that those cut in cubes were expensive in comparison to other formats.

"I find the price of the cut fruit as too expensive. Comparing the ones cut in quarters, the cup ones are just too expensive for me."
"Compare to those in quarters or halves, FCW are very expensive."

While the users of FCW recognised the price that they had to pay for the convenience, they perceived it as a good value for their money.

"When you buy whole fruit, you pay for it by the weight, and the weight of the watermelon itself is much heavier than the actual fruit. By buying the fresh cut one, you only get fruit and pay the same the same amount. And also, the convenience of cutting. I don't like cutting at all."

Conversely, FCW was perceived to have the lowest level of freshness and deteriorates quickly, and therefore, should be eaten right away.

"I think that once cut, the watermelon deteriorates quickly because of its water content."

In contrast, the whole watermelon was perceived to be the freshest and most inexpensive, but the most inconvenient format (Fig. 3.11). Those cut in halves and quarters fall in between the range of FCW and the whole one (Fig. 3.11).

3.3.2.2 Reasons for buying and non-buying of FCW

FCW was bought mainly because of the refreshing and healthy feeing benefits users got from the convenient and right portion package of watermelon (Table 3.7).

> "It is refreshing. In hot weather, it's one of the go-to's."
> "The cubed watermelon is nice. You don't feel its heavy and it is pretty healthy. It is nice to have it as a snack."

For the current end-users, the FCW was a good value for their money (Table 3.7).

> "When you buy whole fruit, you pay for it by the weight, and the weight of the watermelon itself is much heavier than the actual fruit. By buying the fresh cut one, you only get fruit and pay the same the same amount."

They would normally buy FCW when they are all by themselves and when they are either at work or at university (Table 3.7).

> "It depends also where you want to eat the watermelon… If I eat in my office, I'd buy the cut one."
> "I eat this product once a month now because I'm no longer in uni.. but the last time I was in uni, I would eat it at least once every week."

In contrast, the current non-user participants would normally buy the whole one or those in halves or quarters when they have to buy watermelon for their family, having a party or having friends around (Table 3.7).

> "When I bought FCW the last time, I think it wasn't as fresh I wanted it to be."
> "I would but those in quarters or halves when friends come over but maybe twice a year."
>
> "I usually buy half-watermelon and prefer to eat with other people to make it worthwhile consuming it."

These participants prefer to cut their own fruit because they have time to prepare (Table 3.7).

> "I just prefer to buy the whole thing and do it myself as I want to."
> "I like those in whole because I do have the time."

Table 3.7. Reasons given by participants for buying or not buying FCW.

Reasons for buying	Reasons for non-buying
Refreshing and healthy feeling	Drier, not as fresh as the whole or quarter
Convenient	Habit – prefer to cut fruit
Right portion size	Available time to prepare
Good value for money	Expensive – very expensive
For myself, when in Uni or at work	For family, when having a party or friends come over

They perceived FCW as expensive, and therefore, opted for either whole ones or those in halves or quarters (Table 3.7).

> "FCW charge more. They are very expensive compared to those in halves or quarters."

Most importantly, they thought of FCW as less fresh compared to the other formats (Table 3.7).

> "There are ones pre-packed in cubes but I would not go for those often… I think sometimes they can be a little bit drier than when it is cut in half but that must be purely down to because they were pre-packaged."
> "I feel they start to go off or to degenerate a bit once they're cut-up in pieces so they are not as fresh."

3.3.2.3 Valued product cues in buying FCW

Freshness was the main consideration for buying FCW (Fig. 3.12). The participants would look at the date information in the pack in order to assess freshness and safety (*packing* and *date* in Fig. 3.12). Currently, they said that they looked at the UBD information. However, they would prefer to have the packed on date (POD) in order to assess the freshness and safety of the product.

> "Packing date would influence my purchase. This would allow me to gauge the freshness of the product."
> "The date of packing is more important than UBD."

Next to packing date, how the product looks was what the participants use to gauge product freshness. They would look at the colour, fresh appearance and the juice at the bottom of the package.

> "Less colourful means not quite fresh."
> "If there is too much juice the product must be sitting there for too long."
> "Too much juice at the bottom looks like melon is drying out."
> "I'd presume that more water at the bottom means less flavoured cubes."

When asked about why freshness is important, they related it to better health and nutrition.

> "Freshness is important because of high nutrients; the fresher it is the more nutrients it should hold."

Aside from the freshness of the product, the price of FCW was also another consideration (Fig. 3.12). The price point sensitivity of the participants to FCW product is between AU$2.00 and AU$4.00.

> "Price matters in my purchasing decision"
> "I guess I'd buy it for AU$4.00… if it's going to be more than that, it would not be a good value for my money."

Fig. 3.12. Most frequent words associated to valued product cues for buying FCW.

Note: Word cloud generated from NVIVO 12.

Other than price and date information, the list of ingredients, especially the presence of any preservative in the label information, would matter in the purchase of FCW (Fig. 3.12). Even awareness of the role of preservatives to maintain freshness, the absence of the ingredient would be preferred. The participants would want the FCW to be as natural and safe as possible.

> "Labelling information is important to me. Manufacturing should put information like ingredient information and about preservatives (if any is used). I want to know if it's natural and safe."

The convenience of the product was also an important consideration in buying FCW. The general concept of convenience carried the same meaning for all participants, which was not needing to prepare, and hence ready-to-eat. Additionally, to some participants, convenience also meant the right portion size and easy to eat with the availability of the spork. Other elaborations on the meaning of convenience were that the product was easy to carry or easy to stack in the fridge.

3.3.2.4 Improvement suggestions for the current FCW format

Suggestions to improve the current FCW format were provided by the participants. The most common improvement suggestion was to maintain the freshness of the current FCW format while on the retail shelves and during consumption (Fig. 3.13). A suggestion to vary the current portion size was made. The current portion size was enough for some while too much for others. For the latter group, the current portion size was considered as a meal replacement. Thus, a suggestion to decrease the portion size similar to what was shown during the discussion was given. The smaller portion size is a total weight of 160 g with five to six cubes, each cube with 2.5 cm x 2.5 cm x 2.5 cm size. This smaller portion size, however was described as a dessert or a fruit snack to those who prefer the current bigger portion size. The participants also suggested to change the placement of the spork in the current format. The way it was inserted in between the watermelon cubes makes the plastic wrap sticky and messy.

Fig. 3.13. Most frequent words associated to improvement suggestions for the current FCW.

Note: Word cloud generated from NVIVO 12.

Consequently, the participants suggested to put the spork on top of the cubes. The placement of the spork in the suggested smaller portion size, however, was suggested to be on the side, as the container was shallower compared to the current format.

The cup shape packaging of the current format was fine to some participants. To them, this was most convenient when eating at work, university or anywhere away from home. Others, however made a suggestion to change the packaging shape into a square container. Some commented that the watermelon cubes were more compatible to a regular square shape container rather than an irregular cup shape container. A change into square container may also assist in preventing bruised on the cubes, and thus maintain freshness. Moreover, the square container allows for sufficient and maximised storage space for the product in the fridge.

3.3.3 Results of cue-attribute-perception linkage to product components.

The cue-attribute-perceptions linked to product components that can be changed in order to transform the existing FCW, are shown in Fig. 3.14. The sensory cues such as taste, flavour, smell and visual appearance were associated to the freshness and naturalness of the FCW identified as the superior benefit delivered from the purchase and consumption of FCW. Freshness and naturalness were important to current and potential end-users as they relate to benefits of health, nutrition and pleasure from eating refreshing, good quality and safe FCW. Another superior benefit identified from purchase and consumption of FCW was convenience, for which the current end-users associated to good value for their money. The cues linked to convenience were that product requires less time to prepare, is right proportion size, easy to eat and easy to carry and store. The perceived value related product cues identified were linked to product components. For instance, the taste and smell cues of FCW were linked to the natural volatile composition of the fruit, and the visual appearance to the amount of juice leakage, flesh colour and intact cubes. Label information was linked to the addition of a POD to the mandatory UBD. The convenience cue of ease to carry and store was linked to varying the packaging shape of the container. The former examples are related to the transformation and improvements in the core product design while the latter to the actual product design (Fig. 3.14)

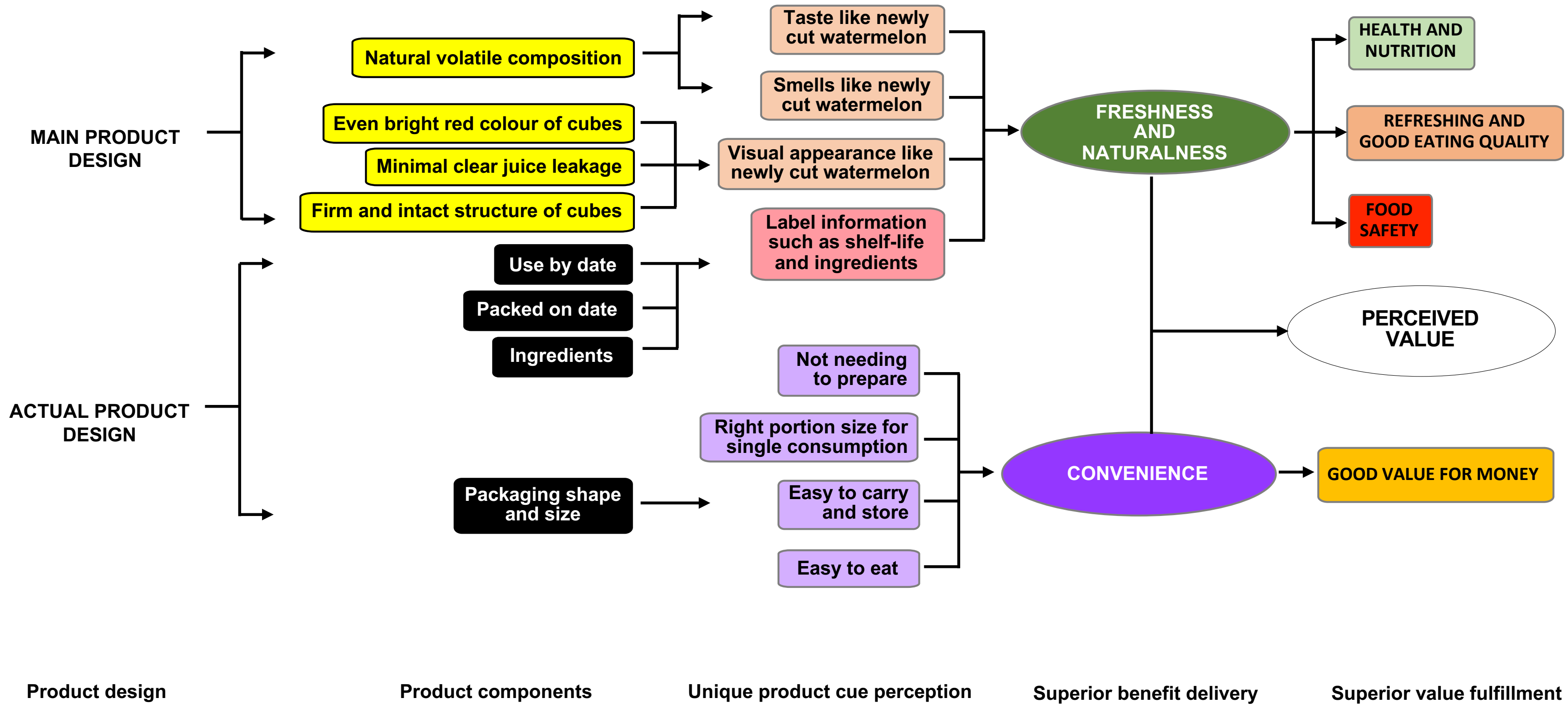

Fig. 3.14. Linking perceived value to product components for the improvement of FCW.

3.4 Discussion

This research was to generate ideas based on value perceptions in order to guide the innovation using the PVI model. This was achieved through the implementation of the idea generation phase of the PVI model. This phase included the elicitation of determinants and deterrents of purchase and non-purchase, value perceptions, and related product cues through consumer surveys and in-depth interviews. The experimental set-ups for these research methods were conducted in supermarkets and central location, respectively.

Consumer surveys using the BWS were performed in supermarkets in order to easily gather information from current and potential end-users of FCFs. An experimental set-up was prepared as close as possible to the display of FCFs in order for participants to easily associate their response to the product category. These participants were also shoppers in the supermarket, and hence, an intercept-administered survey was carried out. This method of interview facilitates the completion of the interview within the limited time (5-7 minutes) as participants were guided through the questions and responses were recorded by the researcher. Additionally, separate in-depth interviews with mini groups and individuals were carried out in order to target innovation for a specific FCF example. The experimental set-up was prepared in a central location which was accessible to willing participants and conducive for interview discussions that went for 60 to 90 minutes.

Both the current and potential end-users were considered in both experiments in order to capture wider demands and varying perceptions and thus, expand potential markets for FCFs. The surveys and interviews were limited to Sydney, Australia because the largest market of FCFs in the country is recorded in this main city. The outcomes of research innovation efforts would therefore be focused, and yet have a significant impact. In addition, the research was to determine the value perceptions and related product cues that most influence purchase and non-purchase of FCFs.

3.4.1 Applicability of consumer survey and interview to idea generation phase

The consumer survey was first carried out in order to collect consumer perceptions of the general FCF category, and to identify the determinants and deterrents of purchase. Understanding the perceptions for FCF allowed for identifying which product related cues require strengthening and changing in order to cater to the demands of the end-users. Although Likert scale has been commonly used to carry out consumer surveys, BWS was utilised to allow for a more convenient way of eliciting consumer responses. Likert scale usually takes time and a lot of thinking for respondents to carry out the tasks while BWS requires easier tasks from respondents. The former provides a minimal discrimination between attribute while the latter allows for easier comparison of the attributes (Lockshin et al., 2015). Moreover, the Likert scale uses survey constructs or statements that are highly related to the stated importance of respondents rather than their actual behaviour (Trope and Liberman, 2010). The stated importance would normally take on the long term consequence of the behaviour, and hence, although called relevant factors, do not necessarily impact purchasing decisions (van Dam and van Trijp, 2013). The survey constructs of BWS, on the other hand, relate more to the actual behaviour of respondents (Lockshin et al., 2015). For instance, in this study, the participants were asked to identify the most and least important determinants and deterrents of purchasing behaviour for FCFs. Determinants or deterrents such as product quality, convenience and price relate more to the actual behaviour than the stated importance of respondents (van Dam and van Trijp, 2013).

The BWS data were collected in this study in order to determine factors that have motivated the current end-users or deterred the non-users to purchase FCFs. The determinants of purchase were selected based on the common product cues searched during the purchase of FCFs and similar convenience products (Table 3.1). For deterrent factors associated with non-purchase of FCFs, published studies are scarce. Thus, the selection for these relevant factors (Table 3.2) was based on the reasons for non-buying of fresh produce, which is the most closely related food to FCFs. The unidimensional definition of perceived value was taken into consideration in this context wherein the end-user makes a trade-off between perceived benefits against product price prior to purchase (Zeithaml, 1988). The knowledge gained from this study, was needed for further research using the PVI model to focus FCF innovation on maximising the perceived value.

A separate in-depth interview study was carried out next in order to understand the value perceptions and related information for FCFs with FCW as the model test sample. Focusing on the model test sample allowed for the concentration of research innovation efforts and maximisation of resources in order to achieve the research goal. FCW was selected for the model by the industry collaborators as the demand for it was high compared to the other FCFs available in the Sydney market. The excessive weight, size and the time required to cut the whole fruit were the reasons for the growth in demand. Fresh-cut packaged solutions for watermelon are therefore ideal and significantly increase convenience and appeal of the fruit (Schmilovitch et al., 2015). The refreshing flavour and unique texture of FCW also makes it to be among the most popular FCFs in the USA (Cook, 2014). The ability to sell this value-added product, however, depends on the value perceptions of the end-users in comparison to its alternatives in the retail market.

Laddering technique was used during the in-depth interview because it was appropriate for the goal of the study that is to improve an existing product based on perceptions against its alternatives. Product improvement was possible by linking product components to the value perceptions through the related product cues important to the end-users during purchase. Laddering interviewing technique is used to understand the knowledge structure of the end-user for a product category or specific product. The understanding on how consumers respond to product cues is important for developing effective food marketing and communication strategies (Verbeke and Liu, 2014). This knowledge structure provides information about the specific linkages between product components and the value orientations of the end-users (Van Kleef et al., 2005). The product components of FCFs could be modified and therefore, guide the innovation experiments.

The product-related consumer information derived from the interviews and surveys were linked to the product components of FCFs using the means-end chain analysis. This analysis assumes that consumers value the benefits they get from the products (Grunert and van Trijp, 2014b), which are referred to as the benefits gained from buying and consuming FCW. The specific linkages of FCW attributes to product components, and to the benefits and perceived value of the end-users for the product are shown in Fig. 3.14.

3.4.2 Outcomes of PVI Phase 1 model implementation

The idea generation phase implementation allowed for determining the value perceptions and related product cues influencing purchase and non-purchase as the basis for guiding FCF innovation. The consumer survey results confirmed a low frequency of buying FCFs in the market (Fig. 3.4) even though the rate of familiarity for these products was high (Fig. 3.3). The low buying frequency can be attributed to poor fresh appearance of FCFs in the retail shelves. Freshness was the main important product factor to both current and potential users in buying FCFs (Figs. 3.7 and 3.9). The same result was revealed from the in-depth interviews, whereby freshness was considered as the most valued product cue in buying and consumption of FCW (Fig. 3.12). These results support the study of Ragaert et al. (2004) that freshness is equally important in both purchase and consumption stages of FCFs. The participants of the in-depth interviews perceived the current FCW format as not fresh enough, and thus, suggestions to maintain product freshness were given (Fig. 3.13).

Other reasons for low or non-buying of FCFs were price and low trust in its quality (Fig. 3.9). The current non-buyers perceived the product as too expensive, and not a good value for their money especially that most of them have the time to prepare and cut their own fruit (Fig. 3.9 and Table 3.7). The price perception for FCFs was similar to the results of the study of Jaeger and Rose (2008), where FCFs were less likely to be chosen due to a 50 % price premium. Their study, however, looked at smaller fruits which may not necessarily require ample time and effort to prepare, compared to bigger and heavier fruits such as watermelon and pineapple. The participants of the in-depth interviews also did not trust the quality of the FCFs, and hence suggested that label information should include the list of ingredients, especially on addition of preservatives. Both users and non-users would want the FCFs to be as natural as possible. This concern about naturalness of FCW and other FCFs agrees with the study of Brunner et al. (2010), whereby the same concern was identified as one of the strongest predictors for buying and consumption of convenience products.

Nonetheless, FCFs were valued for the convenience of eating fresh, natural, healthy but difficult to prepare fruit such as watermelon and pineapple (Table 3.7). The current end-user participants highly recognised the convenience of having to consume fresh and healthy snack, dessert or meal replacement when they purchase FCW (Fig. 3.14). The convenience experienced from eating FCW was described as not requiring further preparation, and sufficient proportion size for single consumption. Additionally, convenience was described as being easy to carry and store, as well as, easy to consume (Fig. 3.14). The superior value fulfillment for convenience was associated to good value for money (Fig. 3.14). Thus, price was not so much of a concern, compared to those non-user participants who have the time to prepare their watermelon, was that they prefer to cut their fruit and do not trust the quality of the product (Table 3.7 and Fig. 3.9). Nevertheless, those non-user participants who would buy FCW and other FCFs in the future would be willing to buy these products if the price falls between AU$ 2.00 and AU$ 4.00. Overall, regardless of the type of participant, when they would buy FCW and other FCFs, they require a fair compromise in price between convenience and quality (Baselice et al., 2017).

The superior value benefits for product quality, such as freshness and naturalness, were linked to health and nutrition, refreshing and good eating quality experience, and food safety. During purchase, the participants would evaluate the freshness and naturalness of FCW by assessing the colour and fresh appearance of the cubes. Visual inspection of the product was possible through its transparent packaging. They would also look for the ingredient and shelf-life information in the packaging label, particularly, the presence of additives and date information. The UBD information is mandatory requirement for this product category (FSANZ, 2011). The expiration date, which is closely linked to UBD, was associated to healthiness, product shelf-life, and a decrease in product quality similar to the results of the study of Van Boxstael et al. (2014). The participants, however, strongly valued the presence of a POD information on the label of FCFs in addition to the UBD as this gives them more confidence in the safety and quality of the products. Similar results are scarce in literature, and therefore, the addition of POD on the label may significantly influence the increase of purchase and consumption of FCFs and related products. During consumption, the participants would link their satisfaction of the freshness and naturalness of FCW when the product looks, smells and tastes like a newly cut watermelon (Fig. 3.14).

The value perception and product-related cues that were important to the participants were linked to its product components in order to improve the core and actual product designs of the current FCW format (Fig. 3.14). The core product design represents the main characteristics of the product such as nutritional contents and flavour while the actual product design refers to the packaging and design which include labelling and brand (Armstrong and Kotler, 2009). For example, the taste and smell of a newly cut watermelon were associated to the natural volatile composition of the product, which can be used as an indicator of the changes in the sensory characteristics of the stored watermelon. Additionally, the brightness of red colour, minimal juice leakage, and firm and intact structure of cubes, which were linked to the visual appearance can also be used to gauge freshness. Product cues that are part of the actual product, such as label information and packaging shape, were identified as product components that can be transformed in order to improve the current format of FCW (Fig. 3.14). For the label information, the POD information can be provided in addition to the UBD. The ingredient list could include the fruits in the package and preservatives added, if any.

3.5 Conclusion

The PVI idea generation phase was implemented which resulted into determining the value perceptions for FCFs with FCW as the test sample. The consumer survey using BWS and in-depth interviews using mini groups and individuals were useful to elicit the consumer information that were relevant to the improvement of the current FCW format. The product cues that mostly influence the perceived value, and therefore, the preference and purchase for FCW were related to freshness, naturalness and convenience. The intrinsic product cues were linked to the product components such as volatile compounds, colour and fresh appearance. These product components can be used as indicators of freshness and naturalness, and therefore, useful for testing the improvement of the core product design. Additionally, product cues such as packaging container and shelf-life information may also be changed in order to test for the improvement of the actual product design. These extrinsic product cues are related to both convenience and freshness of FCW and therefore, useful for the testing of the perceived value of developed FCW formats.

Chapter 4 PVI Phase 2 Implementation: Technical innovation

This research addresses the second subsidiary research question formulated in Chapter 2: *Can industry-appropriate postharvest techniques and a research tool that combines the subjective and objective measurements improve the perceived value of FCW in the technical innovation phase of the model?* It presents the implementation of the technical innovation phase of the PVI model for FCFs (Fig. 4.1) with watermelon (FCW) as the test sample. This Chapter relates to Chapter 3 by utilising the consumer information, that is the perceived sensory freshness of FCW, as the focus of the FCF innovation.

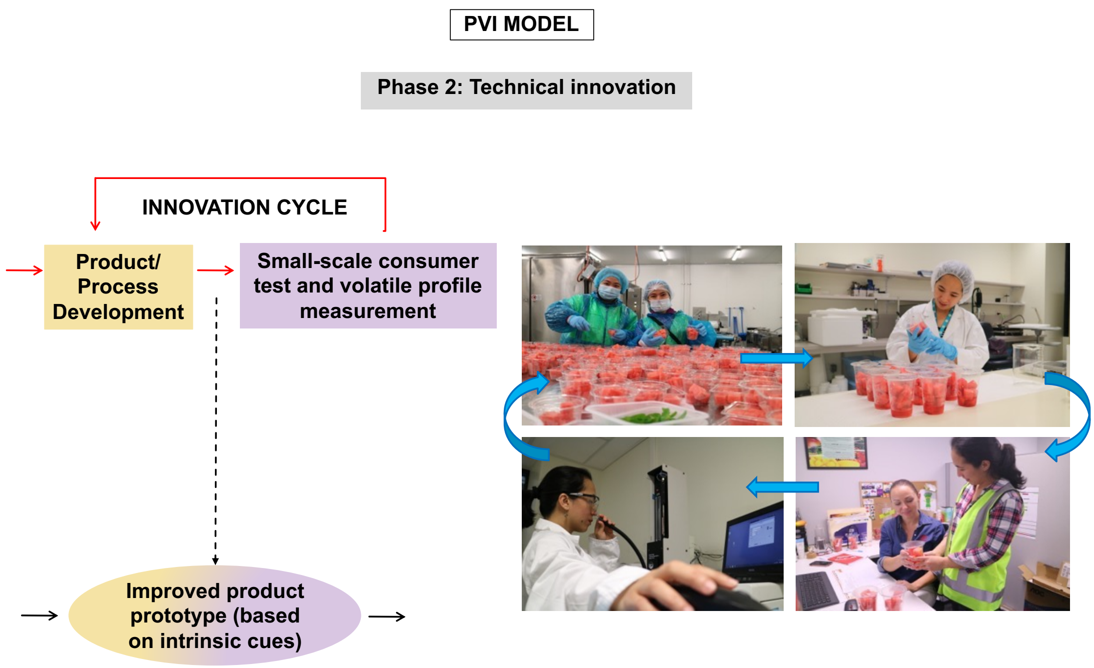

Fig. 4.1. Technical innovation phase (Phase 2) of PVI model.

Note: Photo reproduction with signed consent from the participants.

4.1 Introduction

Freshness and naturalness impact the perception and preference of consumers. The alteration of the natural and fresh appearance, flavour and taste of the FCW determines their perceived sensory shelf-life. The perceived sensory shelf-life refers to the period at which products are acceptable until changes in the sensory characteristics are detected as undesirable (Giménez et al., 2012). Maintaining or extending the perceived sensory shelf-life of commercially produced FCFs, such as fresh-cut watermelon, (FCW) is a major challenge for the industry due to high perishability and microbial issues. FCW is among the most popular fresh-cut fruits in the USA (Cook, 2014). However, once sliced, it is extremely perishable, limiting the shelf-life at retail level (Cartaxo and Sargent, 1998). Currently, the maximum extended shelf-life of FCW is around five to seven days (Stranieri and Baldi, 2017). An extension of the current perceived sensory shelf-life of FCW, even by one day, would therefore be desirable in the context of achieving extra time for sales and for consumer storage.

Many studies on postharvest processing and packaging technologies of FCW, and other FCFs, focused only on extending the microbial shelf-life (Belletti et al., 2008; Mantilla et al., 2013; Raiputta et al., 2012) and nutritional quality (Streif et al., 2009). These studies, however, often fail to evaluate the impacts that postharvest technologies have on the perceived sensory freshness of FCW. The best potential consumer response for perceived sensory freshness may therefore fail to be achieved. This study on the technical innovation phase of the PVI model has addressed this research gap using FCW as the test example.

The perceived sensory quality of FCW is limited by off-odour development, discolouration, juice leakage, texture loss and microbial growth (Zhuang et al., 2011). In the commercial production of FCW, and other FCFs, fresh-cut quality is generally only assessed visually, and flavour quality is seldom assessed, before or after processing (Beaulieu and Baldwin, 2002). Good flavour, however, is critical for consumer acceptance and repeat purchase (Beaulieu and Baldwin, 2002). Flavour deteriorates faster than appearance quality (Beaulieu et al., 2004). It is thus, a better indicator of the perceived sensory freshness (Kader, 2008). Maintaining flavour quality during marketing and consumer storage through postharvest processing and packaging techniques therefore presents a major challenge (Forney, 2001).

Studies relating the impacts of postharvest techniques on FCW quality and consumer acceptability are limited. Many studies have concentrated on the impacts of FCW postharvest treatments on weight loss, appearance and internal gas composition (Cartaxo and Sargent, 1998; Fonseca et al., 1999; Mao et al., 2006; McGlynn et al., 2003; Petrou et al., 2013; Ramos-Villarroel et al., 2012; Saftner et al., 2007). Only the studies of Artés-Hernández et al. (2010), Fonseca et al. (2004), and Smith et al. (2017) have attempted to relate the effects of postharvest treatments on flavour quality and overall acceptability of FCW, as measured by a consumer panel. As a result, the relationship between the physiological changes of FCW, and the quality perceived by consumers, is still poorly understood.

Consumer testing determines the product acceptability of FCFs and other fresh produce over the postharvest handling and distribution period (Plotto et al., 2015). The information from consumer testing is useful in assessing the effects of preconditioning techniques on quality and determining the optimal storage and handling conditions (Baldwin, 2002). Thus, carrying out consumer tests is practical for selecting effective postharvest techniques to produce FCW with high perceived sensory freshness. In addition to sensory evaluation, instrumental measurements improve the ability to objectively determine perceived sensory freshness (Baldwin et al., 2007). The combination of objective and subjective measurements can provide a more holistic approach to improve the FCFs.

In this study, the results of consumer acceptability were therefore linked to volatile measurement in order to provide a useful research tool for improving the perceived freshness of FCW. Additionally, the impacts of processing and storage variables on flavour volatiles profile and the perceived sensory freshness were determined. Specifically, the impacts of postharvest treatments such as modified atmospheric packaging (MAP), post-cut sanitation spray and inclusion of mint leaves on the perceived sensory-shelf-life of FCW were investigated for a potential 20 % extension of shelf-life. The testing of each postharvest treatment was treated as each innovation cycle (IC) (Fig. 4.2). In order to determine the most acceptable prototype of FCW, the following experimental steps were carried out as shown in Fig. 4.3. The details of each step are described in the subsections of Section 4.2.

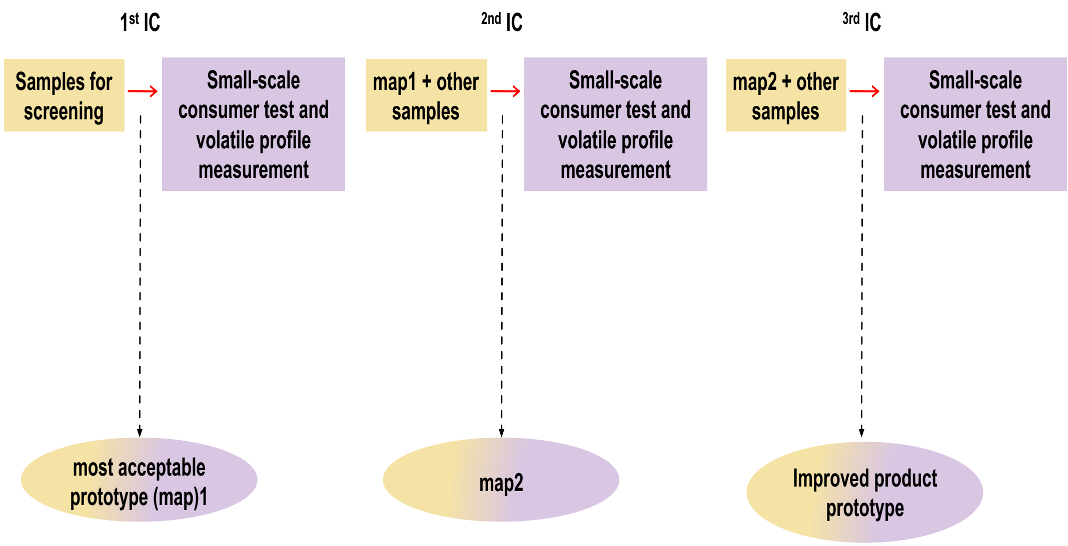

Fig. 4.2. Innovation cycles in Phase 2 of PVI model.

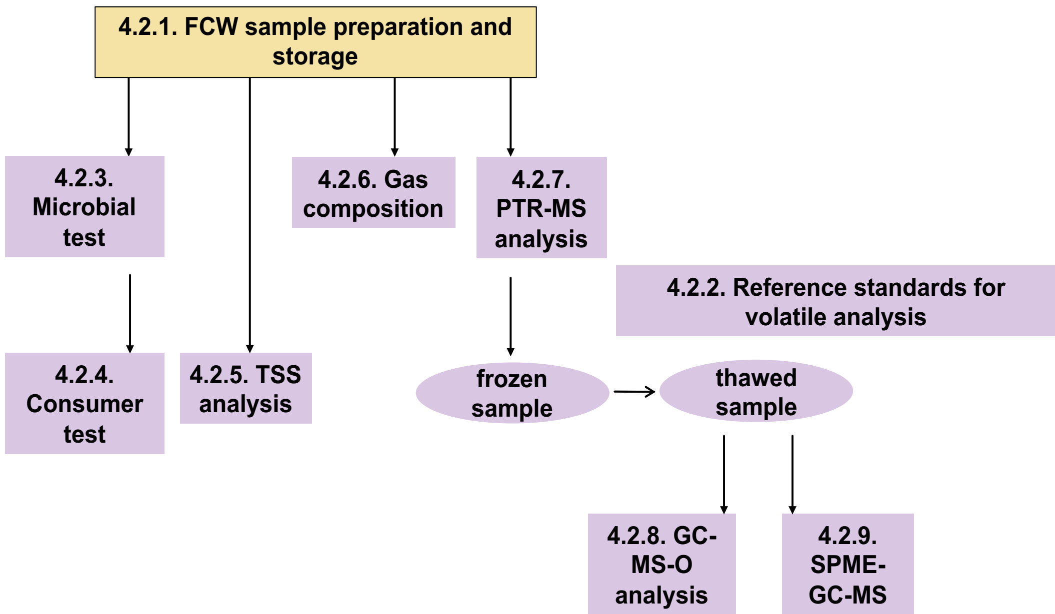

Fig. 4. 3. Implementation steps for Phase 2 of the PVI model.

4.2. Materials and methods

4.2.1 Fresh-cut watermelon sample preparation and storage

4.2.1.1 Samples for testing effects of MAP applications

Samples used to test the effects of MAP on the perceived sensory freshness through consumer acceptability and changes in volatile compounds of FCW were prepared, based on the published protocols of Mendoza-Enano et al. (2019a). Red seedless watermelons (Royal Armada cultivar; ˜3–5 kg; 30–40 pcs) meeting a commercial maturity specification of TSS between 8 and 10 %, were sourced from local market suppliers. Delivery was done in the evening to minimise postharvest changes due to heat. Upon arrival, they were stored at 8 °C and processed within one day. FCW was prepared in a commercial food grade cool facility (9–10.5 °C). Whole fruit were pre-washed in 150–200 mg L^{-1} peracetic acid sanitiser (Bioxysan 20; iH2OM Integrated Hygiene Management Pty. Ltd., Qld, Australia) for two minutes and cut in half to reject any with flesh damage such as water soaked and less intact cubes, discolouration and %TSS determination. Melons meeting the specifications were cut into 2.5 cm × 2.5 cm × 2.5 cm cubes, excluding the rind. Damaged cubes were rejected, and intact cubes were sanitised, when needed as a treatment, on a conveyor line by passing through a light water spray (3 L min^{-1}) with peracetic acid (150–200 mg L^{-1}), generating minimal run-off. Peracetic acid concentration was monitored using a peracetic acid test paper strip (MQuant™; Merck KGaA, Darmstadt, Germany) and was maintained within recommended limits (150–200 mg L^{-1}). The application of this sanitiser was commonly practiced in the commercial facility. The cubes, up to a batch weight of 10 kg, were collected at the end of the line into rectangular plastic crates with drainage holes to remove excess liquids. Cubes (approximately 200 g) were placed into polyethylene (PET) plastic shaker cups (top diameter 105 mm, bottom diameter 63 mm, and height 120 mm; TACCA Industries Pty Ltd, New South Wales, Australia). A 1–1.5 cm headspace was left to allow for sealing with either non-perforated or perforated lidding film (multi-laminate K-Peel; KM Packaging, UK). The manufacturer's ratings for the oxygen transfer rate (OTR) of the K-Peel 5 G AF non-perforated film were < 45 cm^3 m^{-2} $24h^{-1}$ at 23 °C, 85 %RH and for K-Peel 3 G AF perforated, < 75 cm^3 m^{-2} $24h^{-1}$ at 23 °C, 85 %RH. Perforations in the lidding film were either 6 × 150 µm (larger perforation) or 6 × 75 µm diameter perforations (smaller perforation) as described in Table 4.1.

Cups with an initial modified atmosphere treatment were vacuumed to 0.1 MPa and then flushed back to atmospheric pressure with 5 %O_2 and 10 %CO_2, balanced with 85 %N_2 (Airliquide, Australia) using a commercial semi-automatic sealing machine with four heads (Proseal GTR Rotary Table Heat Sealing Machine, Australia). The rest were sealed immediately under atmospheric conditions without gas flushing. Twenty-four replicate samples (n = 24 consumers) per treatment (fresh at 0 d; with and without initial modified atmosphere; with varying types of lidding film) per day of testing (1, 6 and 8 d) were stored at 3 °C in a cold room (Table 4.1). A total of 360 individual cups were tested by the consumer panel. Additional cups (n = 4 replicates) were made up for the treatments and stored at 3 and 7 °C for 1, 6 and 8 d for volatile headspace measurements (n = 148 cups).

Table 4.1. Experimental treatment conditions of FCW.

Sample code	Innovation cycle (IC)	Treatment	Day storage	Initial modified atmospheric condition [a]	Lidding film [b]	Post-cut sanitation	Mint leaves inclusion
Fresh	1st	Control; without post-cut sanitation	0	No	P	None	None
AP [c]	1st	Air perforated; with post-cut sanitation	1, 6 and 8	No	P	Yes	None
MP	1st	MAP perforated; with post-cut sanitation	1, 6 and 8	Yes	P	Yes	None
MN	1st	MAP non-perforated; with post-cut sanitation	1, 6 and 8	Yes	N	Yes	None
Mp	1st	MAP perforated; with post-cut sanitation	1, 6 and 8	Yes	p	Yes	None
Ap	1st, 2nd	Air perforated; with post-cut sanitation	1, 6 and 8	No	p	Yes	None
AN	1st, 2nd, 3rd	Air non-perforated; with post-cut sanitation	1, 6 and 8	No	N	Yes	None
ApL	2nd	Air perforated; with post-cut sanitation	1, 6 and 8	No	p	Yes	Yes; non-visible
ApVL	2nd	Air perforated; with post-cut sanitation	1, 6 and 8	No	p	Yes	Yes; visible
ANL	2nd	Air non-perforated; with post-cut sanitation	1, 6 and 8	No	N	Yes	Yes; non-visible
ANVL	2nd, 3rd	Air non-perforated; with post-cut sanitation	1, 6 and 8	No	N	Yes	Yes; visible
AnT	3rd	Air non-perforated; without post-cut sanitation	1, 6 and 8	No	N	None	None
AnTVL	3rd	Air non-perforated; without post-cut sanitation	1, 6 and 8	No	N	None	Yes; visible

Total weight of sample per cup was 200 $\pm$ 10g
[a] MAP gas combination: 85 %N_2, 10 %O_2, 5 %CO_2
[b] P = Perforated film (polyester-based multi-laminated film with larger perforations i.e. 6 x 150 µm diameter perforations per cup; OTR = < 75 cm^3 m^2 $24h^{-1}$ at 23 °C, 85 %RH)
[b] p = Perforated film (polyester-based multi-laminated film with smaller perforations i.e. 6 x 75 µm diameter perforations per cup; OTR = < 75 cm^3 m^2 $24h^{-1}$ at 23 °C, 85 %RH)
[b] N = Non-perforated film (polyester-based multi-laminated film without perforations; OTR = < 45 cm^3 m^2 $24h^{-1}$ at 23 °C, 85 % RH)
[c] AP = current industry offering

4.2.1.2 Samples for testing effects of mint inclusion

The inclusion of mint on FCW was tested by using sample preparation methods based on the published protocols of Mendoza-Enano et al. (2019a) and according to the preparation of the most acceptable prototypes in the first innovation cycle (Section 4.2.1.1). The best packaging shelf-life outcome for FCW was found to be formed under a non-perforated lidding film. Prior to sealing with non-perforated lidding film, one big (5 cm x 2.5 cm) or 2 small (3 cm x 2 cm each) good quality mint leaves (free from discolouration and physical damage) were carefully placed in between the cubes near the headspace prior to sealing. These mint leaves were sourced from local market suppliers, pre-washed with 150 - 200 mg L^{-1} peracetic acid sanitiser for 2 min, drained and trimmed with sanitised stainless-steel scissors. Filled cups were also sealed with either non-perforated or perforated lidding film but only with smaller perforations (6 × 75 μm diameter perforations).

Two separate small-scale consumer tests were conducted to test the effects of the inclusion of the mint leaves to the perceived sensory freshness of FCW. While the first test used mint leaves as a visual cue, the other test used the herb as an odour cue (Table 4.1). Twenty-two replicates (for n = 22 consumers) per treatment per day of testing (1, 6 and 8 d) were stored at 3 °C in a cold room for each of the consumer tests (Table 4.1). Half of the samples in the first test used visible mint leaves while the other half of the samples in the second test used an infused mint flavour on FCW samples. To make samples with infused mint odour, leaves in half of the batch samples were removed and resealed at each time prior to testing. A total of 396 individual cups were tested by the consumer panel. Additional cups (n = 6 replicates) were made up for the treatments and stored at 3 °C and 7 °C for one, six and eight days for volatile headspace measurements (n = 144 cups).

4.2.1.3 Samples for testing effects of post-cut sanitation treatment

The effects of post-cut sanitation spray on FCW were tested using sample preparation methods based on the published protocols of Mendoza-Enano et al. (2019a) and the preparation of the most acceptable prototypes in the second innovation cycle (Section 4.2.1.2). Samples without post-cut sanitation were also similarly prepared except that they were not subjected to the peracetic acid sanitiser. Twenty-four replicate samples (n = 24 consumers) per treatment (with and without post-cut sanitation spray; with and without mint leaves) were also kept at 3°C in a cold room and tested after storage of one, six and eight days (Table 4.1). A total of 336 individual cups were tested by the consumer panel. Additional cups (n = 6 replicates) were made up for the treatments and stored at 3°C and 7°C for one, six and eight days for volatile headspace measurements (n = 144 cups).

4.2.2 Reference standards for volatile analysis

Reference compounds were used to confirm the identity of most volatiles. Hexanal, 1-heptanol, *(E)*-2-hexenal, octanal, dimethyl trisulfide, 2-pentylfuran, *(E,Z)*-2,6-nonadienal, 1-octen-3-one, 1-octen-3-ol, *(Z)*-2-penten-1-ol, *(E,E)*-2,4-heptadienal, *(Z)*-6-nonen-1-ol, 3-octanone, *(Z)*-6-nonenal, 1-nonanol, 2-butanone, 3-methylbutanal, ethanol, *(D)*-limonene, 2-pentylfuran, 3-methylbutanol, 1-octen-3-one, *(E)*-2-heptenal, 1-hexanol, *(Z)*-3-hexen-1-ol, nonanal, *(E)*-2-octenal, acetic acid, decanal, *(β)*-linalool, acetone, acetophenone, *(α)*-pinene, *(β)*-myrcene and 4-methyl-1-pentanol (internal standard, IS) were of greater than 98% purity and supplied by Sigma Aldrich (Castle Hill, NSW, Australia). Other volatile compound references, namely: 1-penten-3-ol, *(E)*-2-octenal, *(E)*-2-nonenal, eucalyptol and 1-penten-3-one were obtained from Givaudan (ex-Quest International). Helium gas and compressed air were supplied by Coregas (Sydney, Australia), silane treated glass wool and saturated alkanes standard C7-C40 came from Supelco (Bellefonte, USA), Tenax® porous polymer adsorbent (Tenax-TA, 60/80 mesh) from Sigma-Aldrich (Castle Hill, Australia) and Milli-Q water was obtained from Synergy UV Millipore (Sydney, Australia).

4.2.3 Gas composition

The headspace gas composition of each treatment was measured using methods based on the protocols of Mendoza-Enano et al. (2019a) using a portable F-950 Three Gas Analyzer (ProFresh Systems Pty Ltd, QLD, Australia). Measurements were recorded at day 0 for fresh samples and 1,6 and 8 d for stored samples. The measurements of $\%O_2$ and $\%CO_2$ were converted to mmol kg^{-1}.

4.2.4 Microbial test

The food safety of samples was confirmed by the results of microbial analysis. Samples were sent to an accredited commercial testing laboratory for the safety limits of total faecal coliforms, *Escherichia coli*, *Staphylococcus, Salmonella spp*. and *Listeria monocytogenes*. These samples were replicates of the FCW in various treatments that were stored at 3 °C for one and eight days and used for consumer tests.

4.2.5 Consumer testing

Small-scale consumer tests were carried out by 22-24 untrained consumer panellists, all familiar with and users of packaged FCW using published protocols (Mendoza-Enano et al., 2019a). The same pool of participants was used for all sessions and all sessions were performed under consistent lighting and temperature conditions. On the day of evaluation, samples were removed from cold storage (3 °C), labelled with 3-digit codes and presented to consumer panellists in randomised order. The consumer panel consisted of 54 % females. The age ranges were: 42 % (18–30 years), 25 % (31–40), 17 % (41–50) and 17 % (51–60) and the cultural backgrounds were: 38 % (Asian), 33 % (European), 21 % (Australian) and 8 % (Middle Eastern). Signed consent was obtained from participants before each session as part of the requirements of human ethics approval granted by the University of Tasmania (H0015933).

Four sets of small-scale consumer tests were conducted to run the innovation cycles of the technical innovation phase of the PV approach in order to produce the most acceptable FCW formats. One set of consumer tests was for testing the effects of MAP; two sets were for the mint inclusion effects, and the last set was for testing the post-cut sanitation spray effects on the perceived sensory freshness of FCW. Each panellist received all treatments (5 samples maximum) on each day (1, 6 and 8 d) as well as freshly cut watermelon (0 d) as shown in Table 4.1. The total number of samples tested at each time point depended on the number of variables tested in each innovation cycle. Water was provided to rinse the mouth between sample testing. A paper scoresheet was given to each assessor to rank each attribute using a 9-point hedonic scale to indicate their liking scores, ranging from dislike extremely to like extremely. For each sample, panellists individually assessed liking for appearance (colour, fresh appearance), odour quality (smell or storage odour), eating quality (firmness, taste and flavour) and overall quality. After evaluation, score sheets were collected, encoded and analysed. The same sensory protocol was conducted for testing the effect of post-cut sanitation spray on the quality of FCW using air non-perforated (with and without post-cut sanitation spray) samples.

4.2.6 Proton transfer reaction-mass spectrometry (PTR-MS)

PTR-MS was performed based on the published protocol of Mendoza-Enano et al. (2019a). Unopened individual watermelon cups (n = 2 replicates) representing various treatments were scanned by the PTR-MS without any further preparation. For each sample, a 0.45 X 13 mm stainless steel needle (26 G × 1.5"; Terumo Corporation, NSW, Australia) was first inserted into the plastic film of each cup to allow flow through of gases. Another stainless-steel needle (0.70 × 38 mm; 22 G × 1.5"; Terumo Corporation, NSW, Australia) was attached to the PTR-MS inlet PEEK tubing using Teflon® Luer-lock fittings. PTR-MS measurements were carried out for each time point using a high sensitivity single quadrupole PTR-MS (Ionicon Analytik GmbH, Innsbruck, Austria), operating in mass scan mode over the mass range (m/z) 35–200 with a dwell time of 100 m/z, and a cycle time of 120 s. The drift tube was held at 600 V, 2.21 mbar, and 70 °C. After inserting the needles to the sample headspace (or the inlet tubing to the Schott bottle for the reference standards), the measurement proceeded with an air flow of 100 mL min−1 for 20 cycles under the conditions described above. After PTR-MS measurements, samples were macerated using a handheld food processor and stored in 50 mL disposable polypropylene tubes (Rowe Scientific, NSW, Australia) and frozen at −80 °C for up to 30 days for GC-MS-O and SPME GC-MS analyses.

Reference volatile standards that were associated with watermelon and mint were scanned to determine the PTR-MS ion fragments of the main OACs, previously identified from GC-MS-O and SPME GC-MS. For each reference standard, 1 µL of each was added to 10 mL Milli-Q water in a 250 mL Schott bottle. The PTR-MS inlet tubing (PEEK – 0.25 mm id, Upchurch Scientific, USA) was connected to the Schott bottle and other inlets via Teflon ® Luer-lock fittings. Volatile profiles of reference standards associated with watermelon were based on the published data of Mendoza-Enano et al. (2019b).

4.2.7 Gas chromatography-mass spectrometry-olfactometry (GC-MS-O)

The GC-MS-O was based on published protocols (Frank et al., 2017). Samples were thawed for 30 minutes at 25 °C in a water bath prior to analysis. Odour-active compounds (OAC) in fresh and stored watermelon were identified using GC-MS-O. Only fresh, six day-stored with mint leaves (ANVL) and, eight day-stored (MN) samples were tested to identify the most important odour-impact volatiles on fresh and stored watermelon samples. The identified OACs were used to quantify the main aroma volatiles by SPME GC-MS and markers of freshness and off-odour development by PTR-MS.

Volatile extracts were prepared by mixing 14 g macerated watermelon samples, 14 g Milli-Q water and 50 µL of internal standard (4-methyl-1-pentanol, 40 µg mL^{-1}) in a 250 mL Schott bottle with a magnetic stirrer for a total of 32 minutes. The bottle was closed with a Teflon coated cap with two Luer-lock fittings. While the inlet was attached to high purity nitrogen gas (Coregas, Yennora, Australia), the outlet was connected to a Tenax-TA trap (100 mg) held in place by glass wool via PEEK® tubing (Alltech, Australia). Volatiles were extracted under nitrogen flow (110 mL min^{-1}) for 30 minutes at room temperature. Traps were subsequently purged with nitrogen gas (10 mL min^{-1}) for two minutes to remove residual moisture prior to desorption. Tenax-TA traps were desorbed at 260 °C for five minutes using a Short Path Thermal Desorption unit (Model TD-5, Scientific Instrument Services Inc., Ringoes, USA) under a flow of helium gas (0.9 mL min^{-1}) into the hot injector (240 °C) of the GC (Varian 3800, Agilent Technologies, Santa Clara, CA, USA). Approximately, 50% of the gas effluent was directed to the sniffing port (ODO-II, SGE, Melbourne, Vic., Australia) and the remaining sample to the ion trap mass detector (Varian 4000, Agilent Technologies, Santa Clara, CA, USA). Volatiles were separated on a polar capillary column (Zebron-WAXplus, 30 m, 0.32 mm, 0.5 µm, Agilent Technologies, Mulgrave, Australia). The column temperature was initially held at 40 °C for five minutes, then increased to 245 °C at 8 °C $minutes^{-1}$ for two minutes. Samples were scanned in electron ionisation (EI) mode at 70 eV over the mass range (m/z) 46–200. For confirmation of the molecular mass of the parent molecular ion, representative samples were also measured in chemical ionisation (CI) mode using methanol as the ionising agent.

The characteristics of extracted volatiles from the samples in Tenax-TA traps were assessed by five trained assessors with prior GC-MS-O experience. Signed consent was obtained from participants before each session as part of the requirements of human ethics approval granted by the CSIRO (LR 1/2013-I) for the GC-MS-O analysis. Odour intensity was measured through a computerised time-intensity scale (from 0 to 10) using SensoMaker® software (Version 1.7) (Pinheiro et al., 2013). The descriptions of odour quality were digitally recorded using GoldWave software (GoldWave Inc., St John's, Canada). Each sample evaluation lasted for 20 minutes. Compounds were identified using the following criteria: comparison of EI mass spectral and CI molecular mass confirmation to searches obtained from the National Institute of Standards and Technology (NIST) software (Version 2.0, United States of America, 2002), semiquantitative volatile data obtained from the constructed watermelon volatile library using the Varian Star proprietary software (Varian Saturn version 6.4.1, Agilent Technologies, Santa Clara, CA, USA), the retention index compared to a reference standard and the odour quality at the sniff port as described by the assessors, when available. For each odour peak, the area under the curve was calculated and replicate data (5 for each sample) were used to calculate means. Recorded descriptions for each odour peak were used to describe the odour quality.

4.2.8 Solid phase microextraction (SPME) GC-MS

SPME GC-MS was used to provide a semi-quantitative measurement of changes in headspace volatile compounds in fresh and various treatments of stored FCW samples. The analysis was performed based on the published protocol of Mendoza-Enano et al. (2019a). The analysis was also carried out to confirm the identity of OACs found in the samples ran through GC-MS-O analysis.

Samples were thawed for 30 minutes at 25 °C in a water bath prior to analysis. A two-gram macerated watermelon sample was weighed into a 20 mL headspace vial and added with 10 µL internal standard (4-methyl-1-pentanol, 40 µg mL^{-1}). The filled vial was immediately sealed with a gas-tight Teflon lined septum. Replicate samples ($n = 3$) were prepared from each treatment. Headspace analysis of samples was performed with an auto-sampler AOC-5000 Shimadzu, using combined Divinylbenzene/ Carboxen/Polydimethylsiloxane SPME fibres (23-gauge, 2 cm, Agilent Technologies, Bellefonte, USA). Volatiles were extracted at 40 °C for 20 minutes and desorbed in a splitless mode at 250 °C for 5 minutes onto the SPME-GC-MS (Shimadzu QP-2010 Plus, Tokyo, Japan). The carrier gas was helium (1.04 mL min^{-1} flow rate). Compounds were separated on a Zebron-WAX column (30 m, 0.25 mm and 0.50 µm; Phenomenex, Lane Cove West, Australia). The initial column temperature was held at 35 °C for five minutes, then increased to 250 °C for five minutes. Detection of volatiles was performed in EI mode at 70 eV over the mass range (*m/z*) 40–250.

Volatiles were identified by matching chromatogram peaks with EI mass spectral in the National Institute of Standards and Technology (NIST) database (Version 2.0), United States of America, 2002) and confirmed by the linear retention indices (RI) of reference compounds. Integrated area data were normalised to the IS and semi-quantitative data (ng g^{-1}) were estimated prior to statistical analysis.

4.2.9 % Total soluble solids (TSS)

TSS analysis was carried out based on the published protocol of Mendoza-Enano et al. (2019a). The mesocarps of four fresh watermelons were divided into four sections: the core, seed cavity, middle and outer parts of the flesh. Each section was cut into 2.5 cm × 2.5 cm X 2.5 cm cubes. Two sets of cubes were prepared from each watermelon section. Right after cutting of the cubes, one set was subjected to post-cut sanitation treatment prior to packing and sealing. Another set was directly filled into polyethylene (PET) plastic shaker cups (top diameter 105 mm, bottom diameter 63 mm, and height 120 mm; TACCA Industries Pty Ltd, New South Wales, Australia) and sealed with non-perforated lidding film (multi-laminate K-Peel 5 G AF; KM Packaging, UK). Immediately after preparation, juice was squeezed from the cubes of each sample and % TSS was obtained by using a refractometer (HI 9680; Hanna Instruments, Woodsocket, RI, USA).

4.2.10 Data analysis

Consumer data, gas composition and volatile data were analysed based on the published protocols of Mendoza-Enano et al. (2019a). All consumer data were recorded in Excel® (Microsoft) and subjected to a Kruskal-Wallis nonparametric test in XLSTAT statistical software (Boston, USA). Preferences were inferred from relative liking scores prior to statistical analysis. Reported overall scores were calculated as the average of liking scores for appropriate sensory components. Mean liking scores of colour and fresh appearance were used to compute the overall appearance while those for storage odour of the cups, flavour and taste of the cubes were used for the overall flavour. Mean liking scores for firmness and the sensory components of the overall flavour were used to compute for the overall eating quality while the scores for all the sensory components were used for the overall quality. All instrumental data were subjected to multivariate analysis of variance procedure (MANOVA) in XLSTAT statistical software. Appropriate post-hoc multiple comparison tests (Conover-Iman for consumer data and Least Significant Difference – LSD for gas composition, volatile data and % TSS) were performed where significant differences were found. Additionally, principal component analysis (PCA) was carried out for the PTR-MS volatile data after normalisation (1/standard deviation) and for the consumer acceptability data using the procedure in JMP 14 (SAS Software, NC, USA). PCA was conducted to summarise the similarities and differences between the samples and to visualise the relationships of variables to changes in volatiles. PLS regression analysis and correlation analysis (Kendall coefficient) were also carried out to determine relationship of liking scores and volatile data using GenStat (16th edition, VSN International, Hemel Hempstead, UK).

4.3 Results

4.3.1 Headspace O_2 and CO_2 composition

The gas composition of packaged FCW samples stored at 3 °C and 7 °C was tested over time (Table 4.2). The data are strongly affected by gas exchange through packaging material and lidding films in addition to changes in the physiological activity of the watermelon cubes over time. Initial gas composition and storage temperature also influenced the headspace O_2 and CO_2 concentration (Table 4. 2).

Table 4.2. Changes in O_2 and CO_2 in various packages of FCW.

	O_2 in mmol kg^{-1}				CO_2 in mmol kg^{-1}			
Treatment	**0 d**	**1 d**	**6 d**	**8 d**	**0 d**	**1 d**	**6 d**	**8 d**
				3 °C				
AP	65.0 ^{Ba}	62.1 ^{Aa}	60.8 ^{Ba}	50.9 ^{Ab}	0.7 ^{Bc}	3.2 ^{Gbc}	7.5 ^{Dab}	12.2 ^{DEa}
Ap	65.0 ^{Ba}	42.3 ^{Db}	38.2 ^{Cc}	34.6 ^{Bd}	0.7 ^{Bc}	7.7 ^{EFb}	13.7 ^{Ca}	17.2 ^{Da}
MP	14.8 ^{Cc}	55.9 ^{Bb}	64.0 ^{Aa}	56.2 ^{Ab}	29.9 ^{Aa}	18.2 ^{Bb}	5.6 ^{Dc}	9.8 ^{Ec}
Mp	15.0 ^{Cd}	39.4 ^{Ea}	38.0 ^{Cb}	33.0 ^{BCc}	29.9 ^{Aa}	16.2 ^{Cb}	16.1 ^{Cb}	17.8 ^{Db}
MN	14.5 ^{Ca}	13.7 ^{Fa}	0.3 ^{Fb}	0.0 ^{Fb}	30.2 ^{Ab}	22.8 ^{Ac}	38.1 ^{Aa}	40.7 ^{Ba}
AN	67.2 ^{Aa}	56.0 ^{Bb}	23.9 ^{Ec}	12.0 ^{Ed}	0.9 ^{Bd}	6.5 ^{Fc}	28.3 ^{Bb}	38.3 ^{Ba}
AnT	67.2 ^{Aa}	53.6 ^{Cb}	31.3 ^{Dc}	28.7 ^{Cc}	0.9 ^{Bc}	10.2 ^{Db}	24.5 ^{Ba}	28.3 ^{Ca}
AnTVL	65.0 ^{Ba}	55.6 ^{BCb}	32.7 ^{Dc}	19.3 ^{Dd}	0.7 ^{Bd}	8.6 ^{Ec}	23.4 ^{Bb}	59.0 ^{Aa}
				7 °C				
AP	65.0 ^{Ba}	60.3 ^{Ab}	23.9 ^{Dd}	42.1 ^{Ac}	0.7 ^{Bb}	6.3 ^{Fb}	62.1 ^{ABa}	84.4 ^{CDa}
Ap	65.0 ^{Ba}	49.7 ^{Bb}	35.1 ^{Bc}	31.1 ^{Bd}	0.7 ^{Bc}	11.4 ^{DEc}	77.9 ^{Ab}	111.1 ^{ABa}
MP	14.8 ^{Cd}	61.5 ^{Aa}	42.8 ^{Ab}	28.3 ^{BCc}	29.9 ^{Abc}	15.2 ^{Cc}	42.7 ^{Cb}	80.6 ^{Da}
Mp	15.0 ^{Cd}	40.9 ^{Da}	37.7 ^{Bb}	27.0 ^{Cc}	29.9 ^{Ac}	18.2 ^{Bd}	61.1 ^{ABb}	106.5 ^{ABCa}
MN	14.5 ^{Ca}	8.8 ^{Eb}	0.0 ^{Ec}	0.0 ^{Dc}	30.2 ^{Ac}	23.9 ^{Ac}	55.2 ^{BCb}	71.1 ^{Da}
AN	68.0 ^{Aa}	46.9 ^{BCb}	29.7 ^{Cc}	28.7 ^{BCc}	0.9 ^{Bd}	13.4 ^{CDc}	77.4 ^{Ab}	113.8 ^{Aa}
AnT	67.2 ^{Aa}	50.0 ^{Bb}	0.0 ^{Ec}	2.1 ^{Dc}	0.9 ^{Bb}	10.5 ^{Eb}	75.3 ^{Aa}	83.8 ^{CDa}
AnTVL	65.1 ^{Ba}	45.2 ^{Cb}	42.1 ^{Ab}	1.8 ^{Dc}	0.7 ^{Bd}	13.7 ^{CDc}	37.7 ^{Cb}	87.0 ^{BCDa}

Conditions: All samples were stored at 3 °C for 1 to 8 d; AN = air non-perforated; AP = air perforated with larger perforations; MP = MAP perforated with bigger perforations; Ap = air perforated with smaller perforations; Mp = MAP perforated with smaller perforations; MN = MAP non-perforated; AnT = air non-perforated without post-cut sanitation step; and AnTVL = air non-perforated without post-cut sanitation step and with mint leaves; Lidding film with larger perforations have 6 × 150 µm holes while those with smaller perforations have 6 × 75 µm holes; Difference in capital letters corresponds to significant difference among treatments stored and tested on the same day while difference in lower-case letters, to significant difference among shelf-life days within the same treatment ($p < 0.0001$).

Gas concentrations in samples initially packed with ambient air and stored at 3 °C, gradually changed over time especially when perforated lidding films were used. Conversely, the gas concentrations for samples initially packed in modified atmospheric condition (15.0 mmol kg^{-1} O_2 and 30.0 mmol kg^{-1} CO_2) equilibrated to atmospheric O_2 and CO_2 after one day and behaved similarly with samples initially packed with ambient air. Storage at 7 °C over time resulted in a significant drop of O_2 and elevation of CO_2. These abrupt O_2 and CO_2 changes were also observed for samples that used non-perforated lidding film but more so when samples were initially packed with modified atmosphere and stored at higher temperature. Significant changes in O_2 consumption and CO_2 production were decreased by half for samples that were stored at 3 °C when post-cut sanitation spray application was removed (AnT). The inclusion of mint leaves in FCW (AnTVL), in contrast, showed no significant difference with untreated FCW without the mint leaves (Table 4. 2).

4.3.2 Microbial results

All microbial test results for FCW samples in various treatments that were stored at 3 °C for one and eight days and used for consumer tests were within safe limits and tabulated in Appendix 4.1 (*Salmonella spp* not detected; *Listeria monocytogenes* not detected; *Escherichia coli* < 3.0 MPN g^{-1}; total faecal coliform < 3.0 MPN g^{-1}; and *Staphylococcus* count < 100 cfu g^{-1}).

4.3.3 Consumer studies

4.3.3.1 Consumer evaluation on the effects of various packaging conditions

Perceived sensory freshness of FCW samples under various packaging conditions tested in the first innovation cycle were recorded in Table 4.3. Significant differences in odour and flavour liking ($p < 0.005$) were evident in stored samples even after storage for one day. Discolouration of watermelon cubes due to water soaking was evident only after six days and onwards ($p < 0.005$) while deterioration in fresh appearance occurred after eight days ($p < 0.001$). Low fresh appearance liking scores could either be attributed to surface dryness of cubes observed in samples packed in ambient atmosphere with perforated film sealing (AP and Ap) or water soaking observed in samples packed in modified atmosphere regardless of the film (MN, MP and Mp). Texture quality remained intact until six days but deteriorated after eight days ($p < 0.000$). FCW packed in ambient air and sealed with the same film (AN) received the highest visual, flavour and overall acceptability scores up to eight days sensory shelf-life. Those packed in modified atmosphere and sealed with non-perforated film (MN), in contrast, received the lowest scores (Table 4.3). For samples with larger perforations on lidding films (AP and MP), changes in initial atmospheric conditions had no effect on the flavour and overall acceptability scores. Therefore, those samples with smaller perforations on lidding films (Ap and Mp) were also tested after eight days. No significant improvements in liking were observed when perforation size of the lidding film was reduced. Overall, AN sample still showed superiority among all the treatments while MN sample remained the worst one after eight days of storage (Table 4.3).

Table 4.3. Consumer liking scores for FCW packed under various packaging conditions.

Treatment	Mean liking (9-point hedonic scale)						
	Colour	Fresh appearance	Odour	Firmness	Taste	Flavour	Overall
Day 1							
Fresh	6.7 [a]	6.5 [a]	6.7 [a]	6.4 [a]	6.8 [a]	6.7 [a]	6.6 [a]
AN	5.9 [a]	6.0 [a]	5.1 [b]	6.6 [a]	5.8 [ab]	5.5 [ab]	5.8 [ab]
AP	5.7 [a]	5.5 [a]	4.8 [b]	6.5 [a]	5.4 [b]	4.8 [b]	5.4 [b]
MP	6.0 [a]	5.9 [a]	5.1 [b]	6.6 [a]	6.0 [ab]	5.7 [ab]	5.9 [ab]
MN	6.0 [a]	5.9 [a]	4.6 [b]	6.8 [a]	5.5 [ab]	5.3 [ab]	5.7 [ab]
Std. error	0.390	0.404	0.404	0.394	0.379	0.365	0.318
p-val	0.458	0.525	0.000	0.961	0.070	0.005	0.037
Day 6							
Fresh	6.7 [a]	6.6 [a]	6.7 [a]	6.4 [a]	6.8 [a]	6.7 [a]	6.6 [a]
AN	5.1 [ab]	5.1 [a]	5.0 [b]	6.2 [a]	5.6 [ab]	5.1 [ab]	5.3 [ab]
AP	4.7 [b]	4.8 [a]	4.6 [bc]	5.4 [a]	4.8 [bc]	4.7 [b]	4.8 [b]
MP	5.0 [b]	5.2 [a]	4.8 [bc]	5.9 [a]	4.8 [bc]	4.8 [b]	5.1 [b]
MN	5.1 [ab]	5.0 [a]	3.5 [c]	5.0 [a]	4.1 [c]	4.0 [b]	4.4 [b]
Std. error	0.456	0.446	0.415	0.479	0.441	0.433	0.393
p-val	0.003	0.053	< 0.0001	0.204	0.000	0.000	0.000
Day 8							
Fresh	6.7 [a]	6.6 [a]	6.7 [a]	6.4 [a]	6.8 [a]	6.7 [a]	6.6 [a]
AN	5.7 [ab]	5.8 [ab]	4.5 [b]	5.3 [ab]	4.7 [b]	4.7 [b]	5.1 [b]
Ap	5.1 [b]	4.4 [bc]	4.5 [b]	5.0 [ab]	4.9 [b]	4.8 [b]	4.8 [b]
Mp	4.8 [b]	4.4 [bc]	4.4 [b]	4.4 [b]	4.2 [bc]	4.2 [b]	4.4 [bc]
AP	4.6 [b]	4.0 [c]	3.8 [bc]	4.2 [b]	4.0 [bc]	3.8 [bc]	4.1 [bc]
MP	5.0 [b]	4.8 [bc]	4.0 [bc]	4.8 [b]	3.9 [bc]	3.8 [bc]	4.4 [bc]
MN	5.3 [ab]	4.9 [bc]	3.0 [c]	3.7 [b]	3.0 [c]	2.9 [c]	3.8 [c]
Std. error	0.409	0.423	0.384	0.434	0.392	0.398	0.336
p-val	0.001	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	< 0.0001

Conditions: All samples were stored at 3 °C for 1 to 8 d; AN = air non-perforated; AP = air perforated with bigger perforations; MP = MAP perforated with bigger perforations; Ap = air perforated with smaller perforations; Mp = MAP perforated with smaller perforations; MN = MAP non-perforated; Lidding film with larger perforations have 6 × 150 µm holes while those with smaller perforations have 6 × 75 µm holes; Liking scores were based on a 9-point hedonic scale. Means (n=24) with different superscripts are significantly different for that attribute ($p < 0.05$).

4.3.3.2 Consumer evaluation on the effects of mint inclusion

The effects of the inclusion of mint leaves as an odour and visual cue on the perceived freshness of the FCW samples investigated in the second innovation cycle were presented in Tables 4. 4 and 4. 5, respectively. Samples with infused flavour of mint (ANL) were perceived with higher odour ($p < 0.032$) and taste liking ($p < 0.002$) compared to FCW without mint leaves (AN). Nonetheless, the presence of visible mint leaves in stored FCW packs (ANVL) further improved the flavour and overall liking of FCW, and were not significantly different from fresh samples at day 0 (Table 4.5). The visual quality of the mint leaves also did not change significantly over time and thus, did not affect the overall appearance liking of the FCW. The effects of using perforated film with smaller holes to FCW with mint leaves (ApL and ApVL) showed no significant effects to the liking for samples that used non-perforated film.

Table 4.4. Consumer liking scores for FCW with and without infused mint flavour.

Treatment	Mean liking (9-point hedonic scale)						
	Colour	Fresh appearance	Odour	Firmness	Taste	Flavour	Overall
Fresh	6.7 ^{a}	6.8 ^{a}	6.6 ^{a}	6.5 ^{a}	7.0 ^{a}	6.9 ^{a}	6.8 ^{a}
ANL	6.0 ^{a}	6.1 ^{a}	5.7 ^{ab}	6.4 ^{a}	6.0 ^{ab}	5.4 ^{b}	5.9 ^{b}
AN	6.2 ^{a}	6.0 ^{a}	5.2 ^{a}	6.0 ^{a}	5.0 ^{a}	5.3 ^{b}	5.6 ^{b}
Std. error	0.316	0.303	0.375	0.324	0.375	0.395	0.283
p-val	0.257	0.189	0.032	0.469	0.002	0.010	0.019

Conditions: All samples were stored at 3 °C for 1 to 8 d; ANL = air non-perforated with infused mint flavour; AN = air non-perforated without infused mint flavour. Liking scores were based on a 9-point hedonic scale. Means (n= 22) with different superscripts are significantly different ($p < 0.05$).

Table 4.5. Consumer liking scores for FCW with and without visible mint leaves.

Treatment	Mean liking (9-point hedonic scale)			
	Overall appearance	Overall flavour	Overall eating quality	Overall quality
Fresh	6.8 ^{a}	6.8 ^{a}	6.8 ^{a}	6.8 ^{a}
ANVL	6.4 ^{a}	6.0 ^{ab}	6.2 ^{ab}	6.3 ^{ab}
ANL	6.1 ^{a}	5.7 ^{b}	5.9 ^{b}	5.9 ^{b}
AN	6.1 ^{a}	5.2 ^{b}	5.4 ^{b}	5.6 ^{b}
Std. error	0.290	0.355	0.318	0.273
p-val	0.239	0.020	0.033	0.030

Conditions: All samples were stored at 3 °C for 1 to 8 d; ANVL = air non-perforated with visible mint leaves; AN = air non-perforated without visible mint leaves; ANL = air non-perforated with infused mint flavour. Liking scores were based on a 9-point hedonic scale. Means (n= 22) with different superscripts are significantly different ($p < 0.05$).

4.3.3.3 Consumer evaluation on the effects of post-cut sanitation spray

The examination of post-cut sanitation spray effects on the perceived sensory freshness of FCW samples that were tested in the third innovation cycle were shown in Table 4.6. In comparison to the most acceptable prototypes obtained from the previous innovation cycles, samples where the post-cut sanitation step was removed (AnT and AnTVL) exceeded the overall performance of treated samples (AN and ANVL) as shown in Table 4.6 ($p < 0.0001$). Results also confirmed significantly higher overall appearance liking for samples with visible mint leaves in FCW without post-cut sanitation compared to samples without the herb (Table 4.6).

Table 4.6. Consumer liking scores for FCW with and without post-cut sanitation.

Treatment	Mean liking (9-point hedonic scale)			
	Overall appearance	Overall flavour	Overall eating quality	Overall quality
Fresh	6.6 ^{ab}	6.7 ^{a}	6.6 ^{a}	6.6 ^{a}
AnTVL	7.3 ^{a}	7.4 ^{a}	7.4 ^{a}	7.4 ^{a}
AnT	6.4 ^{b}	6.9 ^{a}	6.9 ^{a}	6.8 ^{a}
AN	5.8 ^{b}	4.6 ^{b}	4.8 ^{b}	5.1 ^{b}
Std. error	0.305	0.306	0.297	0.271
p-val	0.006	< 0.0001	< 0.0001	< 0.0001

Conditions: All samples were stored at 3 °C for 1 to 8 d; AN = air non-perforated with post-cut sanitation spray treatment; AnT = air non-perforated with post-cut sanitation spray treatment; AnTVL = air non-perforated with post-cut sanitation spray treatment with visible leaves; Liking scores were based on a 9-point hedonic scale. Means (n=24) with different superscripts are significantly different for that attribute ($p < 0.05$).

4.3.4 Odour active compounds identified by GC-MS-O

A total of 23 odour-active compounds were identified in fresh and stored (MN) samples (Fig. 4.2). Eight of the odours eluted closely to other compounds and were not easily resolved by the assessors, hence were assigned to multiple volatiles. Only odours detected by more than two assessors were considered as genuine odour-active compounds. Most of the odour-impact compounds detected in fresh samples were also found after eight days, however, at different intensity (Fig. 4.2). For example, *(E)*-2-hexenal, 3-octanone, 6-methyl-5-hepten-2-one, *(E)*-2-octenal, *(Z)*-6-nonenal, *(E)*-2-nonenal, 1-nonanol, *(Z)*-6-nonen-1-ol and *(Z,Z)*-3,6-nonadien-1-ol were higher in fresh sample compared to MN sample that was stored for eight days. Typical descriptors related to freshness, green, cucumber and watermelon attributes of these compounds confirmed them as character impact compounds of fresh watermelon, which were also reported in previous studies (Kemp et al., 1974; Yajima et al., 1985).

In contrast, dimethyl trisulfide (DMTS) and acetophenone increase in stored samples and may have contributed to the off-odour smell indicative of non-fresh stored watermelon. In addition, higher odour intensities corresponding to 2-butanone, 1-penten-3-one, hexanal, 2-pentylfuran, 1-octen-3-one, *(E,E)*-2,4-heptadienal, and *(E,Z)*-2,6-nonadienal in stored samples implied a role of these compounds in the odours giving a perception of lack of freshness with corresponding odour descriptors such as chemical, green, metallic vegetable odour, mushroom, burnt roasted potato smell and strong oxidised fat smell.

The compounds found in FCW with mint leaves were similar to those compounds in fresh samples except for the addition of *(α)*-pinene, *(β)*-myrcene, eucalyptol and *(R)*-carvone (Fig. 4.2). Such compounds emitted mint characterising odours described as pine green, earthy and sweetish minty smell. The terpenes, *α*-pinene and *β*-myrcene were described as compounds with green, mint and earthy notes. Eucalyptol and *(R)*-carvone were rather the compounds associated with fresh mint or minty note descriptors.

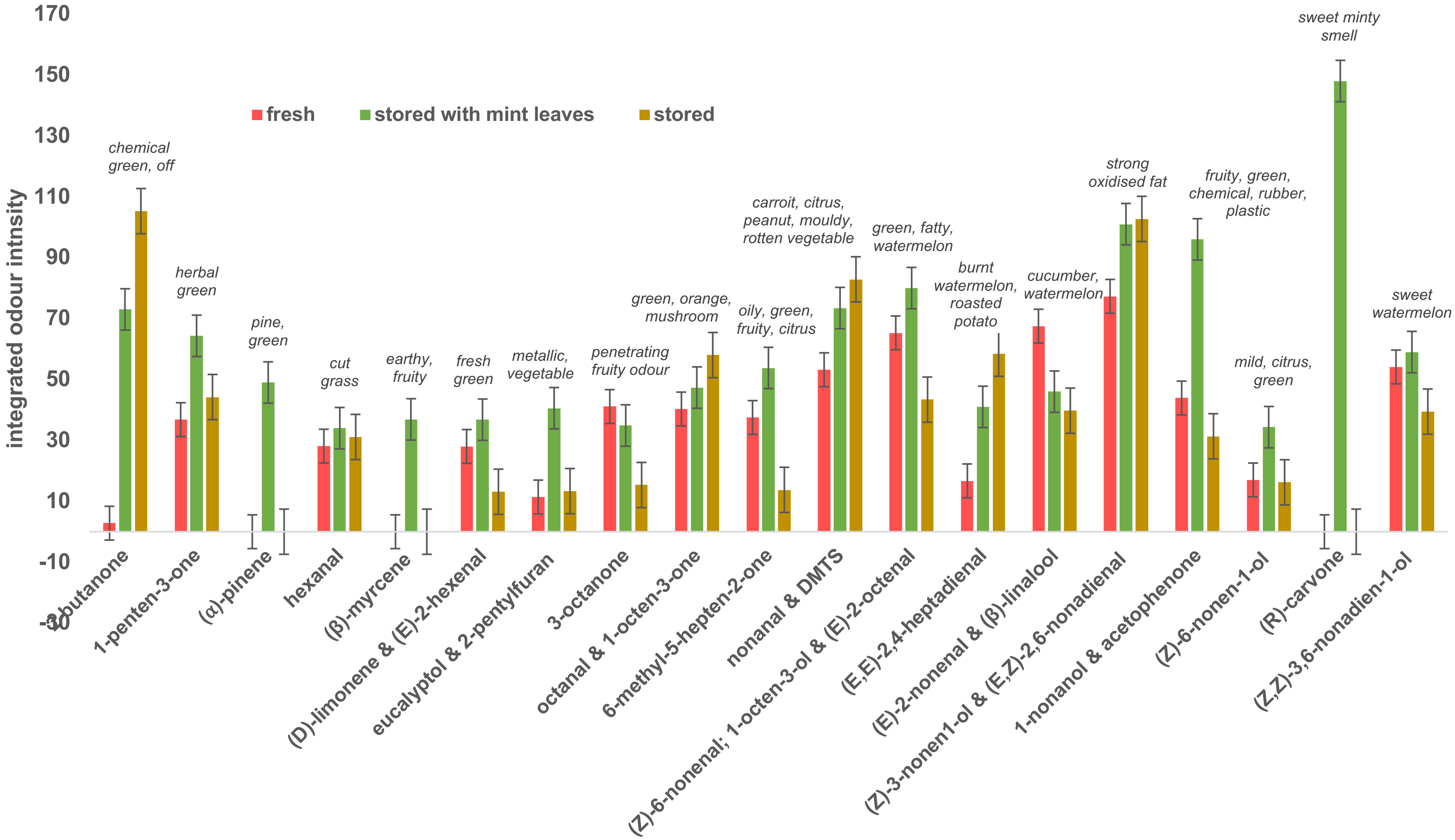

Fig. 4.4. Odour active compounds in FCW under various treatments.

4.3.5 SPME volatile measurement

SPME volatiles of samples were measured at the end of eight days of shelf-life. Forty-one volatiles were identified and quantified by headspace SPME GC–MS allowing comparison across treatments (Appendix 4.2). The odour-active volatiles characterised by freshness at the sniffing port, namely: *(Z)*-3-nonen-1-ol, *(Z,Z)*-3,6-nonadien-1-ol, *(Z)*-6-nonen-1-ol, 1-nonanol, *(E)*-2-nonenal and *(E,Z)*-2,6-nonadienal, were confirmed as abundant in fresh samples ($p < 0.0001$) in accordance with previous reports (Beaulieu and Lea, 2006; Dima et al., 2014; Kim et al., 1999; Yajima et al., 1985). These alcohol compounds significantly decreased by ˜50–80 % ($p < 0.0001$) in all stored samples (Appendix 4.2). The aldehydes also decreased by ˜90 % in stored samples except for MAP Non-perforated (MN) sample. *(E)*-2-nonenal levels decreased very slightly (˜8 %) while *(E,Z)*-2,6-nonadienal increased by two-fold in MN samples relative to freshly prepared. *(E)*-2-nonen-1-ol was also significantly higher by ˜65 % (p < 0.0001) in fresh samples than in stored ones. In addition to *(E,Z)*-2,6-nonadienal, other aldehydes such as nonanal, *(E)*-2-hexenal and *(E,E)*-2,4-heptadienal were also significantly ($p < 0.0001$) higher in MN samples (Appendix 4.2). These compounds are products from the oxidation of the unsaturated fatty acid linolenic acid (Grosch et al., 1976), abundant in watermelon. The concentration of 2-butanone, *(D)*-limonene and 2-pentylfuran were also elevated significantly in MN samples compared to fresh. Acetophenone increased over time in MN samples and may have been formed through catabolism of the aromatic amino acid phenylalanine (Dong et al., 2012). DMTS is formed through the degradation of the amino acid methionine (Ballance, 1961). The increased concentration of selected aldehydes, and the development of DMTS and acetophenone, were potentially responsible for the off-odour of MN sample. While the above-mentioned compounds found in both fresh and MN samples varied in intensity, other odour-active compounds remained the same in both samples, namely: hexanal, *(Z)*-6-nonenal, *(E)*-2-octenal, octanal, 6-methyl-5-hepten-2-one, 1-penten-3-one, 1-octen-3-one and 3-octanone and 1-octen-3-ol.

The difference in initial atmospheric condition significantly influenced the degradation of the cubes as shown by three to four-fold higher ethanol production in MAP compared to storage in ambient air (Appendix 4.2). The use of lidding film with larger perforations (6 × 150 μm diameter perforations), however, allowed the dissipation of most volatiles for both treatments (AP and MP). The levels of ethanol remained unchanged when the size of perforations (6 × 75 μm diameter perforations) was reduced (Ap and Mp). This type of lidding film, however, retained the fresh volatile levels of Ap and Mp samples better. For example, *(E)*-2-nonenal and *(Z)*-3-nonen-1-ol were higher in Ap compared to AP by 26 % and 50 %, respectively. The same fresh volatile compounds were higher in Mp than MP by 94 % and 50 %, respectively. In comparison to air non-perforated (AN) sample, the fresh volatile levels of Ap sample were not statistically different except that fresher odour-active compounds such as nonanal, 2-pentylfuran, 6-methyl-5-hepten-2-one, 1-octen-3-ol and *(E)*-2-hexenal were retained in the AN sample. The AN sample, compared to the treatment with no post-cut sanitation spray (AnT), showed that AnT maintained more abundant fresh odour-active compounds (*(Z)*-3-nonen-1-ol, 1-nonanol and 6-methyl-5-hepten-2-one) while keeping the off-odour compounds (DMTS and *(E,E)*-2,4-heptadienal) at low level, similar to fresh samples (Appendix 4.2).

The inclusion of mint leaves contributed to the presence of odour-active compounds such as *(α)*-pinene, *(β)*-myrcene, eucalyptol, *(R)*-carvone and other volatile compounds such as *(β)*-pinene and dihydro-carvone (Appendix 4.3). Some compounds like *(D)*-limonene and *(E)*-2-hexenal, which are inherently available in FCW increased significantly (p = 0.0001 to 0.05) when mint leaves were added. These compounds, however, were significantly higher in FCW with mint leaves than without mint leaves by thousand-fold and five-fold, respectively (Appendix 4.3). Other odour-active compounds such as hexanal *(E)*-2-octenal, 1-octen-3-ol, *(Z)*-6-nonenal *(E)*-2-nonenal and *(Z)*-6-nonen-1-ol were also found in freshly cut watermelon and samples with mint leaves (Appendix 4.3). In contrast, these aldehydes and alcohols significantly decreased in stored samples by ~50 – 90 % (Appendix 4.3). The ketones, 2-butanone, 1-penten-3-one and 1-octen-3-one were also found to be odour-active in both freshly cut watermelon and stored samples with mint leaves. However, while 2-butanone was significantly higher in stored samples by ~90 %, the two other ketones in the same samples dropped by the same percentage (Appendix 4.3). Other compounds such as 2-pentylfuran, 3-octanone and 6-methyl-5-hepte-2-one were also found in both freshly cut watermelon and mint leaves. Their concentrations, however were not significantly different, regardless of the presence of mint leaves and storage time (Appendix 4.3)

The main fresh watermelon odour-active compounds *(Z,Z)*-3,6-nonadien-1-ol and *(Z)*-3-nonen-1-ol significantly declined in stored samples by ~50 - 80 % (Fig. 4.2). Other fresh watermelon associated compounds, such as octanal and 1-nonanol (green note descriptors), also decreased in stored samples with and without mint leaves by ~70 % and ~90 %, respectively (Appendix 4.3). The odour-active compounds *(E,E)*-2,4-heptadienal and acetophenone on the other hand, were only found in stored products with and without mint leaves, and thus, associated with off-odour development regardless of mint leaves inclusion (Appendix 4.3).

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4.3.6 PTR-MS volatile profile and consumer acceptability

The fragmentation patterns and relative abundance of 32 reference chemical standards (Appendix 4.4) were used to confirm the target mass ion (*m/z*) signals in the volatile profile of watermelon samples. *(E)*-2-nonen-1-ol, *(Z)*-6-nonen-1-ol, *(E)*-2-nonenal and *(Z)*-6-nonenal), which are closely associated with fresh volatile compounds (0 d), were abundant in *m/z* 141 and 123 (Fig. 4.3a). The fragmentation patterns and relative abundance of *(Z)*-3-nonen-1-ol or *(Z,Z)*-3,6-nonadien-1-ol, that were also identified as higher in fresh samples, were not included due to lack of reference standards. The rest were found to be significantly higher in stored samples compared to fresh. Specific ions *(m/z)* were abundant in particular aldehydes, and were used as markers i.e. acetaldehyde (*m/z* 45), citral (*m/z* 59), decanal (*m/z* 67), octanal (*m/z* 69), 3-methylbutanal (*m/z* 87), *(E,Z)*-2,6-nonadienal (*m/z* 95), *(E,E)*-2,4-hexadienal (*m/z* 97), *(E)*-2-hexenal (*m/z* 99), *(E)*-2-octenal (*m/z* 109), *(E,E)*-2,4-heptadienal (*m/z* 111), and hexanal (*m/z* 83, 101). A significant number of these m/z ion signals were also found in 3-methylbutanol (*m/z* 41), 1-octen-3-ol (*m/z* 43), ethanol (*m/ z* 47), *(Z)*-3-hexen-1-ol (*m/z* 55), and *(Z)*-2-

penten-1-ol (*m/z* 57). Others were found in 2-butanone (*m/z* 73), 1-penten-3-one (*m/z* 85), acetic acid (*m/z* 61) and DMTS (*m/z* 127).

To visualise the changes in the identified *m/z* markers, principal component analysis (PCA) models were developed. The recorded volatile organic compound (VOC) headspace concentration of samples measured using PTR-MS were analysed to determine the effects of the initial atmospheric condition, lidding film, storage time, temperature and post-cut spray sanitation on VOC concentration of the identified *m/z* markers. The main factor influencing VOC concentration was storage temperature (Fig. 4.3b) ($p < 0.001$). Storage at the higher temperature of 7 °C (Fig. 4.3b, in red solid triangle) significantly increased the concentration of aldehydes such as decanal (*m/z* 67), octanal (*m/z* 69), *(E)*-2-hexenal (*m/z* 99), nonanal (*m/z* 83, 143), citral (*m/z* 59), 3-methylbutanal (*m/z* 87) and *(E,Z)*-2,6-nonadienal (*m/z* 95). Storage at the higher temperature of 7 °C also promoted the formation of alcohol compounds like 3-methylbutanol (*m/z* 41), 1-octen-3-ol (*m/z* 43), *(Z)*-3-hexen-1-ol (*m/z* 55), *(Z)*-2-penten-1-ol (*m/z* 57) and 1-nonanol (*m/z* 71). The ketones: 2-butanone (*m/z* 73), 1-penten-3-one (*m/z* 85), and 3-octanone (*m/z* 129); fermentation by-products such as ethanol (*m/z* 47) and acetic acid (*m/z* 61); and compounds such as 2-pentylfuran (*m/z* 139) and DMTS (*m/z* 127) also increased with temperature. While these compounds were elevated at higher storage temperature, the concentration of fresh volatile associated compounds like *(E)*-2-nonen-1ol, *(Z)*-6-nonen-1-ol, *(E)*-2-nonenal and *(Z)*-6-nonenal (*m/z* 123 and 141) were significantly reduced.

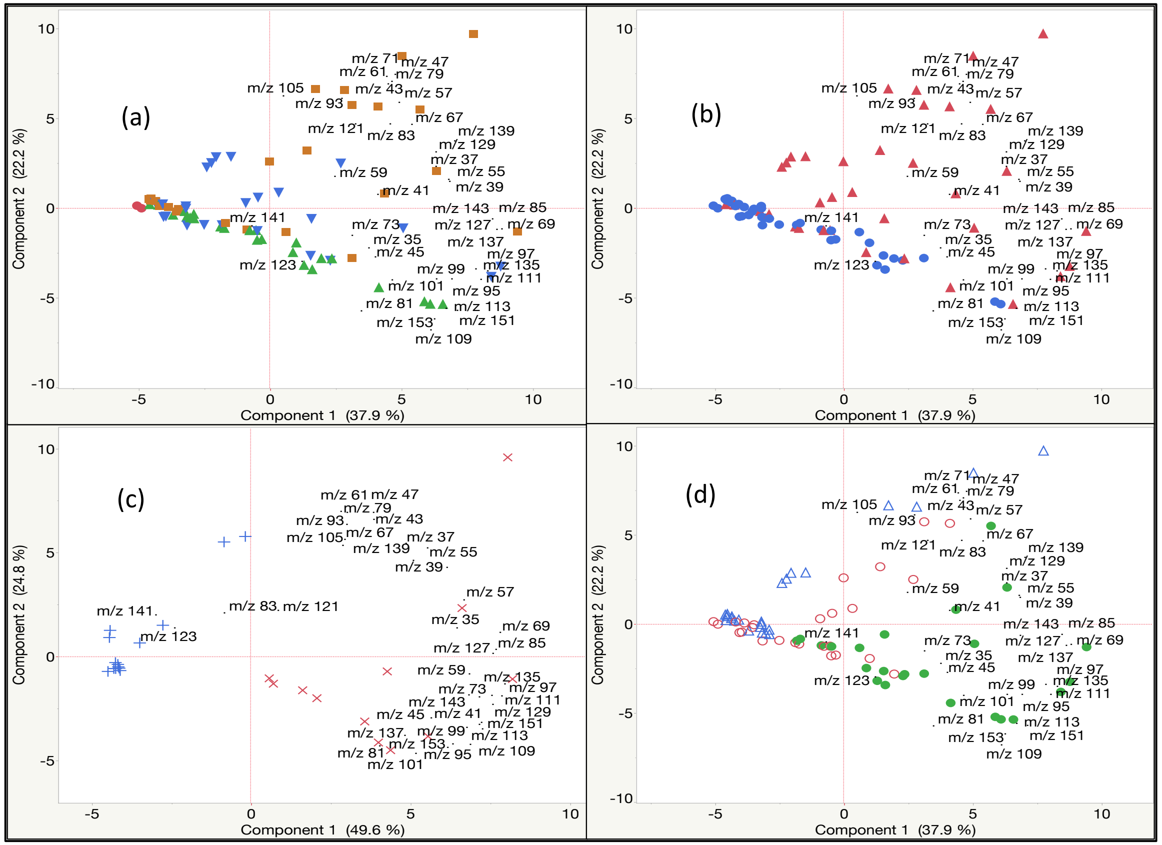

Fig. 4.5. PCA biplot of standardised PTR-MS ions of volatiles in different factors affecting FCW.

Conditions: (a) storage time (0 d = red solid circle; 1 d = green solid triangle; 6 = blue solid inverted triangle; 8 d= brown solid square), (b) storage temperature (3 °C = blue solid circle; 7 °C = red solid triangle) (c) post-cut sanitation treatment (without = red X; with = blue +) and (d) lidding film (non-perforated = green solid circle; smaller perforation = blue hollow triangle; bigger perforation = red hollow circle).

The VOC concentration of the same volatiles that increased with higher storage temperature also significantly increased over time ($p < 0.001$) (Fig. 4.3a) except for some compounds such as 1-octen-3-one (*m/z* 81) and *(E)*-2-heptenal (*m/z* 113). For instance, the longer storage time (8 d in brown solid square) resulted in an increased concentration of 1-octen-3-one (*m/z* 81) which remains unaffected at elevated temperature. Other compounds like the aldehydes *(E)*-2-heptenal (*m/z* 113), hexanal (*m/z* 101), *(E)*-2-octenal (*m/z* 109) also increased in concentration over time regardless of temperature change. Inversely, the concentrations of *(E)*-2-nonen-1-ol, *(Z)*-6-nonen-1-ol, *(E)*-2-nonenal and *(Z)*-6-nonenal (*m/z* 123 and 141) decreased. The concentrations of 3-methylbutanol (*m/z* 41), octanal (*m/z* 69), DMTS (*m/z* 127) and 3-octanone (*m/z* 129), however, were not influenced by storage time as much as by temperature.

Post-cut sanitation treatment (red X in Fig. 4.3c) also influenced the VOC concentration ($p < 0.05$) with more aldehydes affected. Higher levels of acetaldehyde (*m/z* 45), *(E,E)*-2,4-hexadienal (*m/z* 97) and *(E,E)*-2,4-heptadienal (*m/z* 111) were observed in addition to increased levels of aldehydes influenced by storage time and temperature. Moreover, the same ketones and compounds like DMTS (*m/z* 127) and 2-pentylfuran (*m/z* 139) that were influenced by storage time and temperature also developed when post-cut sanitation spray was applied. In contrast, 3-methylbutanol (*m/z* 41) and *(Z)*-2-penten-1-ol (*m/z* 57) were the only alcohol compounds influenced by this treatment.

Modified atmospheric packaging alone did not influence VOC concentration as much as post-cut sanitation, storage time and temperature. ANOVA analysis ($p < 0.05$) indicated that there was a significant influence only in acetaldehyde (*m/z* 45) and 1-octen-3-one (*m/z* 81). The effect of atmospheric condition on VOC concentration was highly dependent on the type of film. The presence and size of perforations in the lidding film greatly affected the VOC concentration (Fig. 4.3d). Perforated lidding film (in red hollow circle and blue hollow triangle for larger and smaller perforations, respectively) permitted the dissipation of most volatiles, an effect that was more observed in film with larger perforations, while nonperforated lidding film (in green solid circle) trapped them. The same compounds influenced by post-cut sanitation were affected by lidding film except for *(Z)*-3-hexen-1-ol (*m/z* 55) and *(Z)*-2-penten-1-ol (*m/z* 57).

The addition of mint leaves in FCW, on the other hand, significantly influenced the VOC concentration in compounds such as *(α)*-pinene, *(β)*-myrcene, eucalyptol and *(D)*-limonene (*m/z* 137) (Fig. 4.4). Nonanal (*m/z* 83, 143) and *(E,Z)*-2,6-nonadienal (*m/z* 95) that are inherently available in FCW also increased significantly when mint leaves were included and hence influenced the VOC concentration of the cups.

The volatile compounds identified through GC-MS-O and SPME GC-MS are shown to be related to the visual (colour and fresh appearance), olfactory (odour, flavour and taste), texture (firmness) and overall liking for different treatments of FCW with and without mint leaves, packed in varying conditions and stored at 3 °C (Fig. 4.4). Highest overall liking for samples with mint leaves (AnTVL_1d, AnTVL_6d, and AnTVL_8d), fresh samples (0 day) and samples without post-cut sanitation spray application stored overtime (AnT_1d, AnT_6d and AnT_8d) were related to high concentration of fresh associated volatiles *(E)*-2-nonen-1ol, *(Z)*-6-nonen-1-ol, *(E)*-2-nonenal and *(Z)*-6-nonenal (*m/z* ions 141 and 123). Consumer dislike for MN samples at six and eight day storage periods on the other hand, could be attributed to high concentration of off-odour compounds such as DMTS (*m/z* 127) and *(E,E)*-2,4-heptadienal (*m/z* 111) and fermentation by-products such as acetaldehyde (*m/z* 45) and ethanol (*m/z* 47) as shown in Fig. 4.4. Liking for all the other stored samples with applied post-cut sanitation spray (AN, AP and MP) falls in between liking for AnT and MN samples. These samples were generally associated with high concentrations of acetaldehyde (*m/z* 45), hexanal (*m/z* 83, 101) nonanal (*m/z* 83, 143), decanal (*m/z* 67) ethanol (*m/z* 47), and acetophenone (*m/z* 105). Higher concentrations of fresh-related volatiles, however, are retained in AN sample compared to AP and MP samples.

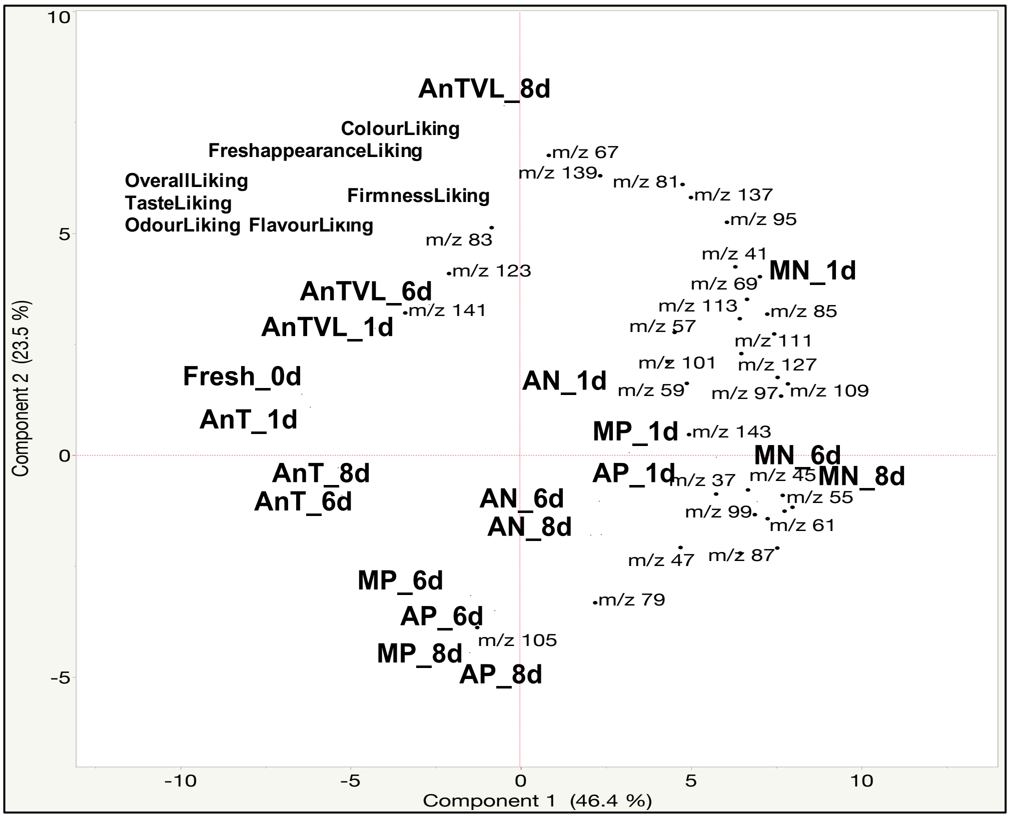

Fig. 4.6. PCA biplot of consumer liking and PTR-MS ions of volatiles in FCW treatments.

Conditions: All samples were stored for 1, 6 and 8 d at 3 °C; AnTVL = without post-cut sanitation spray, air non-perforated packaging, with mint leaves; AnT = without post-cut sanitation spray, air non-perforated packaging; AN = with post-cut sanitation spray, air non-perforated packaging; AP = with post-cut sanitation spray, air perforated packaging; MP = with post-cut sanitation spray, MAP perforated packaging; and MN = with post-cut sanitation spray, MAP non-perforated packaging). Sample signature: AnT_1d = without post-cut sanitation spray, air non-perforated packaging stored for 1 d.

4.3.7 TSS of watermelon with and without post-cut sanitation treatment

The removal of the post-cut sanitation step resulted in higher liking for odour, flavour and taste (Table 4.6). While odour and flavour liking were confirmed by volatile measurements, differences in sweetness were related to % TSS. The post-cut sanitation spray step significantly ($p < 0.005$) decreased the sugar content of FCW by 23 % (average % reduction = TSS before post-cut sanitation treatment –TSS after post-cut sanitation treatment).

4.4 Discussion

This study measured the impacts of the postharvest techniques on the ability to maintain the perceived sensory freshness of the FCW. The influences of processing and storage conditions on volatile aroma compositions have been characterised in order to understand the effects that these variables have on consumer acceptability. Characterisation of volatile compounds was carried out using GC-MS-O while changes in the concentration of compounds was semi-quantified using SPME GC-MS. While these volatile analysis methods were necessary for confirmation of compound identity, PTR-MS was used to rapidly measure volatile organic compounds (VOCs) in the sample headspace. It allowed direct analysis of VOCs to be performed with minimal sample preparation and detection limits down to parts-per-trillion per volume (Aprea et al., 2006). The evaluation of the effectiveness of the postharvest techniques could therefore be rapidly performed using this instrumental analysis.

Linking subjective measurements of liking to the objective volatile measurements was a useful tool to determine most appropriate packaging and storage conditions for FCW. Higher liking scores confirmed higher perceived sensory freshness and acceptability for the products. Odour active compounds associated with perceived sensory freshness, on the other hand, were important indicators or markers to determine other appropriate postharvest processing experiments for FCW in this thesis. This approach has been used to improve the perceived sensory freshness of the FCW. However, the method has wider applicability for other fresh-cut convenience products where freshness is perceived, in part, from the composition of odour-active volatiles. The fresh-cut product industry can use this tool for further testing of other postharvest processing and packaging applications.

MAP technology combined with polymeric lidding films, with or without perforations, has been widely used in the industry to improve the shelf-life of packaged fresh produce. Prior studies, however, have focused only on microbial and visual assessments of shelf-life. MAP was first tested in FCW, through varying O_2 and CO_2 levels in enclosed systems in the study of Cartaxo and Sargent (1998). Their findings showed effective control of microbial growth up to 14 days but apparent juice leakage and discolouration were observed after five days. For future studies, they recommended 5

%O_2 and 10 %CO_2 to minimise physiological disorders while controlling microbial growth. Recently, Smith et al. (2017) used these gas combinations for FCW in combination with low dose electron beam (eBeam) processing. The samples were also packed in a sealed system (i.e. polyethylene clamshells placed in sealed polynylon vacuum bags). Their results showed better product characteristics and microbial growth control for both MAP and MAP-eBeam treated watermelon. However, the evaluation was carried out after only one day.

The impacts of MAP in FCW were re-examined in this research by using the same gas composition but up to eight days storage to determine potential extension of shelf-life by 20 %. Samples were tested against consumer perceived aroma profiles. Gas compositions in the cups were varied using different lidding films such as nonperforated and perforated lidding films with different size and number of perforations. The size and number of the perforations are designed to govern the rate of exchange of oxygen, carbon dioxide, ethylene, and many other gases, while controlling transmission of moisture vapour in or out of the package, beyond the rate of the base film (Gates, 2011). The oxygen transmission rate of the film can be tailored according to the respiration rates for the product inside the package (Gates, 2011). Varying perforation size has a large effect on the exchange rate of gas influencing respiration of fresh-cut produce (Ghosh and Anantheswaran, 2001).

In this research the results of consumer liking and volatile analysis indicated that differences in initial atmospheric packaging conditions and lidding films influenced the flavour acceptability and overall liking up to the end of the eight-day shelf-life. Modifying atmospheric packaging conditions, regardless of lidding films, did not improve the FCW acceptability, as shown by the low flavour and overall liking scores (Table 4.3). Our study confirmed that modified atmospheric condition of 5 %O_2 and 10 %CO_2, recommended in the study of Cartaxo and Sargent (1998) and studied by Smith et al. (2017), has limited applicability to improve the quality of FCW stored at 3 °C from six days onwards. The low O_2 and high CO_2 atmosphere in this study influenced the overall flavour liking. Altered flavour may result from low O_2 and high CO_2 atmospheres through biosynthesis of fermentative volatiles, sugar interconversions and reduction of acidity (Kader, 1986). Potential generators of fermentation volatiles could either come from microbial fermentation or the anaerobic respiration of watermelon cubes. The decline in the overall flavour liking of MAP packed watermelon may be attributed to decreases in key odour-active volatiles (i.e. *(Z,Z)*-3,6-nonadien-1-ol, *(Z)*-3-nonen-1-ol and *(Z)*-6-nonen-1-ol) and an increase in odour compounds associated with stored samples such as DMTS, *(E,E)*-2,4-heptadienal and acetophenone. Fermentation and anaerobic respiration may have occurred in the case of samples packed with modified atmosphere and sealed with non-perforated film (MN) as shown in Table 4.2. This packaging condition led to the faster conversion of sugars into ethanol and acetaldehyde, which is associated with lower O_2 levels. The respiratory demand for O_2 in this sample increased faster than the O_2 permeation and resulted in the decline of O_2 levels inside the cups, thus limiting the usefulness of MAP in this instance (Beaudry, 2000).

The use of perforated film regardless of the perforation size under MAP conditions also showed no improvement in the consumer acceptability of FCW. Although, the oxygen level inside the cup equilibrated with atmospheric O_2 after storage for one day, the elevated CO_2 may have induced stress in the cubes. This stress contributes to the incidence of physiological disorders and increased susceptibility to decay indicated by the loss of fresh flavour and off-odour development (Kader, 2008) in this study. Plant tissues have recovery capacity from stresses due to low O_2 and high CO_2 exposure. Post-climacteric fruits however, are less tolerant to low O_2 levels and have lower capacity for recovery (Kader, 2001). This decreased tolerance to changes in O_2 and CO_2 may be the case for watermelon with very thick rind. The study by Petrou et al. (2013) provided evidence that leaving the rind on could delay senescence of FCW, presumably by decreasing the oxygen stress of exposing all the mesocarp directly to atmospheric oxygen levels. Perforations enhance diffusional flavour volatile loss from the product affecting organoleptic deterioration of food (Del-Valle et al., 2004). Microperforations in this case, therefore, had very little to no additional value in preserving the flavour quality of FCW.

FCW packed in an ambient air condition with non-perforated stored at 3 °C for up to 8 d received the highest overall liking scores among other treatments. These packaging and storage conditions are, therefore, highly recommended for industry application. This result confirmed the study of Fonseca et al. (2004) that showed high acceptability of FCW packed in an enclosed system with greater than 14 %O_2 atmosphere stored at

1–3 °C. Their findings, however, were limited only to use of rigid glass jars which is rarely used by the fresh-cut processing industry. The ambient air in the cup and non-perforated film sealing may have cushioned the change of O_2 and CO_2 condition resulting in a better response of the watermelon cubes. Freshness associated volatiles were retained while off-odour development was minimised resulting in the highest overall liking scores.

Optimising flavour and overall acceptability of FCW was further examined by removing the post-cut sanitation step for the treatment packed in ambient air and sealed with non-perforated film (AnT). Our results (Table 4.4) indicated higher flavour liking for samples without post-cut sanitation (AnT) up to eight days when stored at 3 °C. Volatile measurements confirmed higher retention of fresh volatiles in AnT and TSS analysis further confirmed higher retention of its sweetness compared to the other treatments. Post-cut sanitation treatment is mainly applied to reduce the microbial population that may have contaminated during cutting. This processing step, however, could possibly wash out significant amounts of the volatiles responsible for flavour and total soluble solids responsible for sweetness that limits product acceptability as well as induce osmotic stress. AnT samples, together with samples treated and packed under the same condition (AN) and stored at 3 °C for one and eight days were within safe limits for both samples, confirming that microbial safety was controlled during preparation and storage. The results of gas composition monitoring also indicated lowest respiration for AnT samples stored up to eight days at 3 °C compared to samples with post-cut sanitation. This means that post-cut sanitation spray treatment may have induced increased respiration, in addition to its detrimental effects on perceived flavour and taste of FCW. For industrial applications, the post-cut sanitation spray for FCW processing may be removed provided that good manufacturing practices (GMP) and a hazard analysis and critical control points (HACCP) plan are strictly implemented.

The inclusion of mint leaves as a visual sensory cue was also investigated to enhance the flavour and perceived sensory freshness of FCW. Adding a specific perceptual feature related to freshness may contribute to enhanced perceived sensory freshness, overall liking and improved quality up to eight days maximum of shelf-life. Studies on herbs, particularly on essential oils, have been explored to extend the shelf-life of FCFs (Ayala-Zavala et al., 2009; Belletti et al., 2008; Patrignani et al., 2015) but limited studies have been reported on using minimally processed herbs for fresh-cut products (Gross et al., 2016). Increasing consumers' freshness perception through adding natural and inexpensive herbs complementing flavour quality and visual appeal of the FCW may promote its perceived value. FCW presents a sweet, fresh flavour with characteristic tropical aroma notes (Kader, 2008), which are compatible with fresh flavours like mint, cinnamon, basil, and citrus (Ayala-Zavala et al., 2009).

Mint was selected in this study as it is widely used in food and beverage for its colour (Curutchet et al., 2014), refreshing aroma (Labbe et al., 2009), flavour, fragrance, and antimicrobial properties to its palatability, appeal and microbial safety (Curutchet et al., 2014; İşcan et al., 2002). Results proved the improvement of the visual, flavour and overall liking of FCW when visible mint leaves were added. A significant increase of the odour and taste liking of FCW was also achieved even with only a hint of mint flavour available in the cup, indicating that the aroma was perceived and likeable. The cooling effect of eucalyptol identified as odour active may be associated with the improved perceived sensory freshness when mint leaves were included in the pack (Croteau et al., 2005; Eccles, 1994).

The effects of varying perforated lidding film on the perceived sensory freshness and flavour of the mint leaves in FCW packs were also examined. Although fresh herbs, such as mint sold in supermarkets, are commonly packed in perforated polyethylene or polypropylene bags (Lopresti and Tomkins, 1997), no literature has been reported on the quality response to herbs when packed with a cut fruit in a perforated container. This study, therefore tested different types of lidding film to assess the effects on the quality response to the watermelon and mint combination. Results have shown that the best response to mint leaves was also observed when kept under atmospheric conditions formed by also using non-perforated lidding film. This means that the packaging condition requirement for both FCW and mint leaves are compatible. For industrial applications, mint leaves may be added to improve perceived sensory freshness of FCW. The perceived sensory quality of mint leaves is limited by browning and wilting of the leaves and declining of its fresh smell. Ensuring the sensory quality of the mint leaves therefore must be undertaken to maximise its purpose for improving the perceived sensory freshness of FCW.

4.5 Conclusions

The technical innovation phase of the PVI model was applied to improve the perceived sensory freshness of the FCW. FCW with high perceived sensory freshness was developed using three industry appropriate postharvest processing and packaging techniques that were tested through a combination of consumer acceptability and volatile measurements. MAP technology was found to have only a limited influence on consumer acceptability for FCW stored at 3 °C at the end of one-day shelf-life regardless of the lidding film used. Highest flavour acceptability and overall liking of FCW after eight days of shelf-life were attained when packed in ambient air and sealed with non-perforated lidding film and stored at 3 °C. The removal of the post-cut sanitation treatment further improved the flavour through higher retention of fresh odour-active volatiles, better taste through higher % TSS and increased overall liking of FCW without sacrificing microbial safety. The inclusion of mint leaves also further enhanced the visual, flavour and overall liking of FCW. OACs associated with watermelon freshness and undesirable odours formed during storage can be used to monitor changes in product sensory freshness. Rapid volatile profiling and benchmarking with PTR-MS can therefore be a useful tool to measure the impacts of different packaging technologies, processing techniques, and additional ingredients to optimise FCW quality.

Chapter 5 PVI Phase 3 Implementation: Market testing

This research addresses the question formulated in Chapter 2: *Can simulation of purchase and consumption in the testing phase of the PV approach, using a combination of DCE and informed consumer sensory test, effectively assess the improvement of the PV of developed FCW formats?* Chapter 5 presents the third and last phase of the PVI model for FCF (Fig. 5.1).

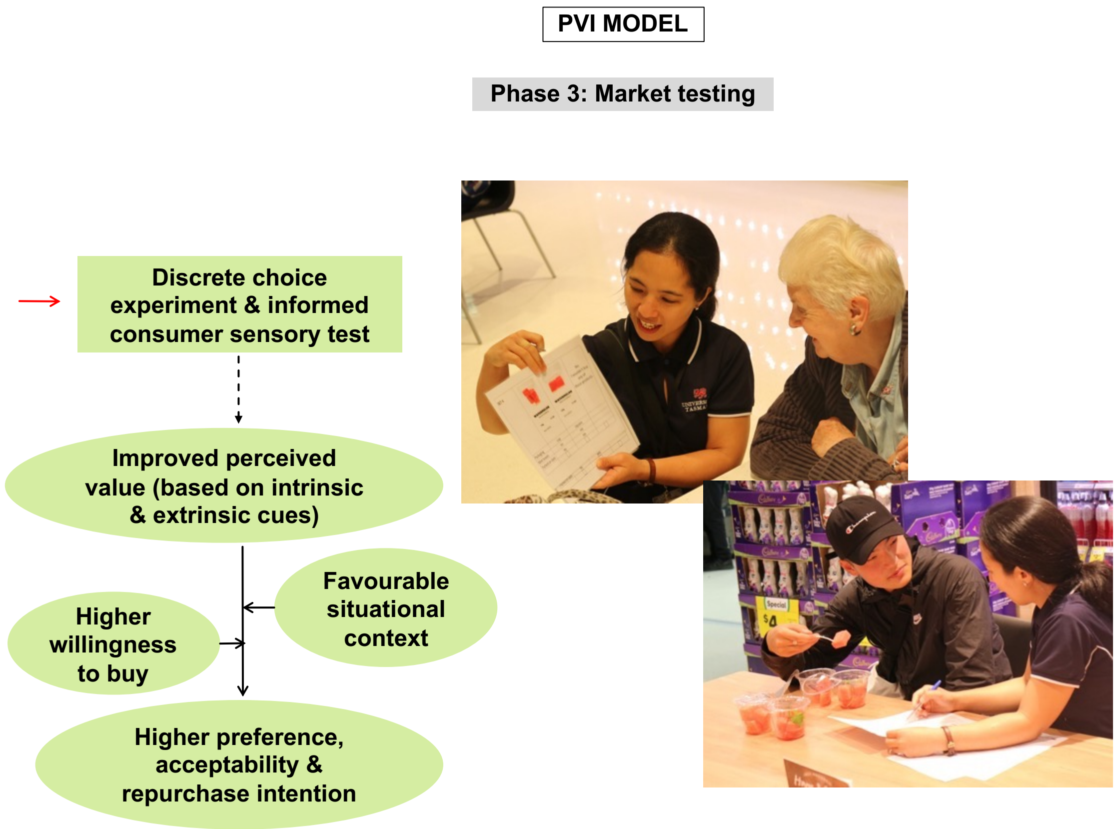

Fig. 5.1. Market testing phase (Phase 3) of the PVI model.

Note: Photo reproduction with signed consent from the participants.

5.1 Introduction

End-users perceive the value of food products at two different points of time: during purchase and during consumption (Sijtsema et al., 2002). PV is the overall evaluation of the benefits of the product based on the perceptions of what is received compared to what is given, referring to the cost (Zeithaml, 1988) during purchase and consumption. The perceptions of convenience, health and freshness were identified as perceived benefits of FCF purchase and consumption (Ragaert et al., 2004). The perception of convenience highly influenced the end-users during purchase while health and nutritional value were more important during consumption. Freshness, on the other hand, remained important during purchase and consumption of FCFs (Ragaert et al., 2004).

Varying important product factors at purchase and consumption stages may influence changes in the perceived value of FCFs (Amini et al., 2014; Gardial et al., 1994a, b). When product expectations, set during purchase, are met during or after consumption, the perceived value remains high. If the perceived value for the product drops, it provides a reason for not repeating the purchase. Companies need to understand the reasons for deviation of perceived value in order to focus on improving those aspects of the product elements during product development. This practice facilitates an efficient implementation of a user-oriented product development process (Amini et al., 2014).

One way to assess the PV deviation is to identify the factors that are important at different stages of purchase and consumption. Identified factors correspond to FCF cues that mostly influence purchase, consumption and repeat purchase, may then be utilised to examine improvement in the PV of FCFs. Demonstrating improvement in the PV of FCFs at different stages of this process can then be used to show the success of the PV innovation model.

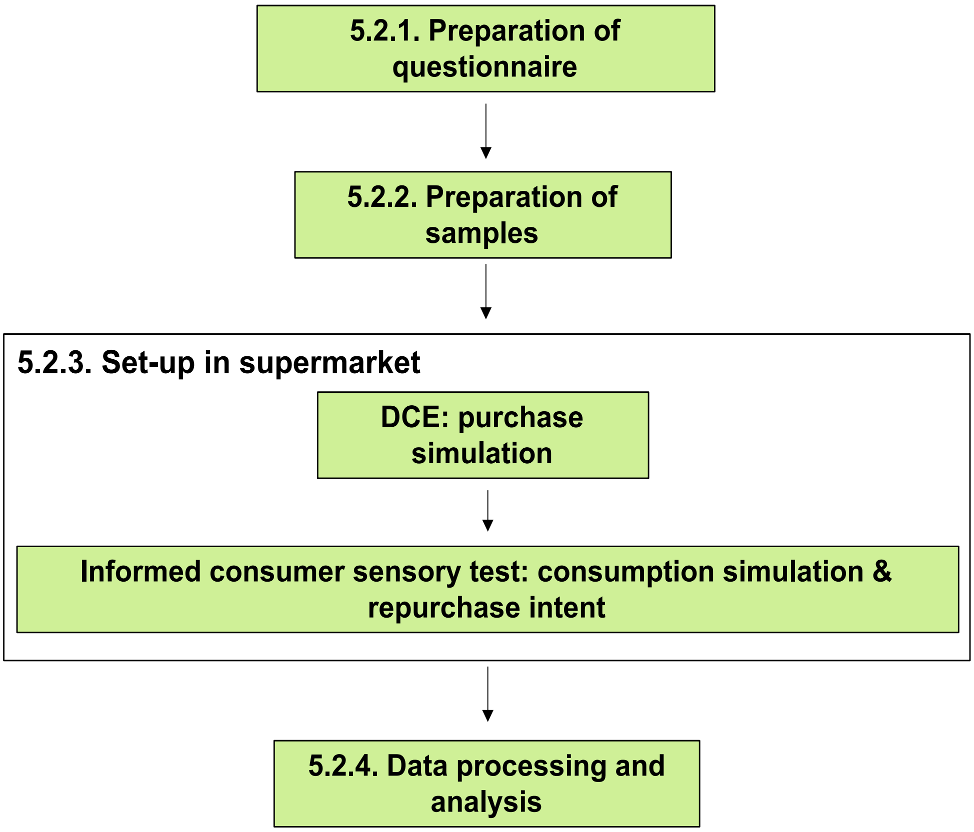

Fig. 5.2. Implementation steps for Phase 3 of the PVI model.

In this study, the PV improvement of FCW formats was therefore tested by integrating a simulated process of purchase and consumption through a DCE and informed consumer sensory testing. Additionally, repeat purchase intention was determined after the consumption simulation. In order to determine the improvement of the perceived value of developed FCF formats, the experimental steps were carried out as shown in Fig. 5.2.

5.2 Materials and methods

5.2.1 Preparation of the questionnaire

The questionnaire was prepared by formulating questions relevant to purchase and consumption behaviour of each participant for the current FCW offering sold in supermarkets. Preference questions for the DCE and product acceptability questions for the informed consumer sensory test were also constructed. The questionnaire was organised in three parts and is reproduced in Appendix 5.1 for reference.

The first part included questions on habits of consumers, in particular questions about familiarity and liking of FCW and mint leaves, frequency of purchase and situation or context when FCW was likely to be consumed. This part included the choice experiment section where the respondents were asked to imagine themselves in the same context when they feel like eating watermelon and indicate their preference per choice set. Respondents were asked to choose among two different FCW formats including an opt-out alternative (three alternatives), each defined by three attributes (packaging container, presence of mint leaves and inclusion of POD information). The experiment included overall nine choice sets. The respondent was asked nine times to choose one alternative per choice set.

The second part included questions to define the socio-demographic characteristics of the respondents. This section provided time for the preparation of the samples for the following informed consumer sensory testing session.

The third part consisted of questions for the informed consumer sensory testing session. Each respondent was asked to evaluate FCW formats one at a time, indicating his or her liking score for each sensory attribute using the 9-point hedonic scale with anchors of (1) as *dislike extremely* and (9) as *like extremely*. The sensory attributes included were colour and freshness appearance of the watermelon cubes, smell, firmness, taste, flavour and overall liking.

5.2.2 Preparation of FCW samples

FCW samples were selected, processed and packed based on the published protocols of Mendoza-Enano et al. (2019a) as presented in Chapter 4. Red seedless watermelons (Royal Armada cultivar; ~3-5 kg; 30 – 40 pcs; each with 8-10 % TSS) were sourced from local market suppliers and were prepared in a commercial food grade cold facility (9-10.5 °C). Whole fruit was pre-washed in 150-200 mg L^{-1} peracetic acid sanitiser (Bioxysan 20; H2OM Integrated Hygiene Management Pty. Ltd., QLD, Australia) for two minutes and cut in half. The knives and cutters were disinfected prior to use. Each half was checked and rejected if there was flesh damage, discolouration or % TSS were not standard range (8 to 10 °Brix). The selected halved melons were cut into 2.5 cm x 2.5 cm cubes of flesh, excluding the rind. Intact cubes (approximately 160 g) were placed into polyethylene (PET) plastic shaker cups (top diameter 105 mm, bottom diameter 63 mm, height 80 mm; TACCA Industries Pty Ltd, New South Wales, Australia) and square punnets (length 75 mm, width 75 mm, height 40 mm; TACCA Industries Pty Ltd, New South Wales, Australia) as shown in Fig. 5.3. Samples were made up to 160 g leaving 1-1.5 cm headspace to allow for sealing with non-perforated lidding film (multi-laminate K-Peel 5GAF; KM Packaging, UK). The rating of manufacturer for gas transmissibility of the non-perforated film was oxygen transfer rate (OTR) of < 45 cm^3 m^2 24h at 23 °C, 85 % RH.

Mint leaves were sourced from local market suppliers. They were pre-washed with 150-200 mg L^{-1} peracetic acid sanitiser for two minutes, drained and trimmed with sanitised stainless-steel scissors. Whole mint leaves, free from discolouration and physical damage, were selected. Mint leaves were added to samples by inserting one or two mint leaves carefully placed between the cubes near the headspace. Samples with mint leaves were also sealed with non-perforated film under atmospheric conditions.

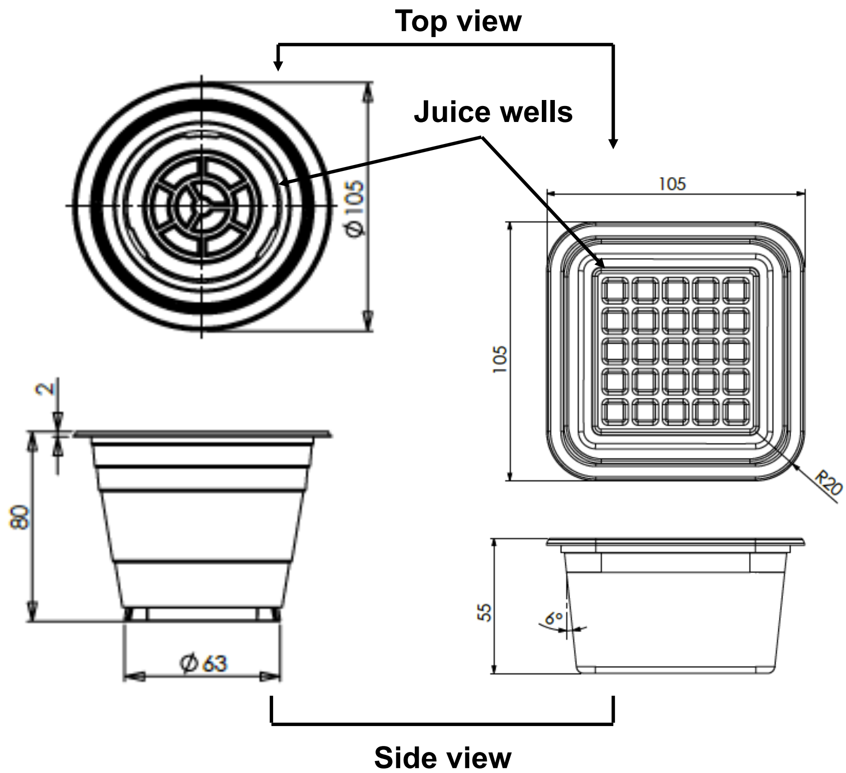

Fig. 5.3. Shaker cups and square punnets.

Source: TACCA Industries Pty Ltd.

Table 5.1. Developed FCW formats for DCE and informed consumer sensory testing.

FCW formats	Description	Packaging shape	Mint leaves	POD
C_M_POD	Cup, with mint, with POD	+	+	+
S_M_POD	Square, with mint, with POD	-	+	+
S_P_POD	Square, without mint, with POD	-	-	+
C_P_POD	Cup, without mint, with POD	+	-	+
C_M_UBD	Cup, with mint, without POD	+	+	-
S_M_UBD	Square, with mint, without POD	-	+	-
C_P_UBD	Cup, without mint, without POD	+	-	-
S_P_UBD	Square, without mint, without POD	-	-	-

Conditions: packaging shape container: cup = (+), square = (-); presence of mint leaves: with = (+), without = (-); availability of packed on date (POD) information in addition to use-by date (UBD): with = (+), without = (-)

A total of 405 replicate samples per treatment (Table 5.1) were prepared each week for four consecutive weeks. These samples were used for four consecutive days in each week in the supermarkets where the informed consumer sensory test was carried out. All replicate samples per week of testing were kept at 3 °C during distribution and handling. Samples were kept chilled in thermally-insulated boxes with cubes of ice. Data temperature loggers were inserted in between the samples to monitor for changes in temperature during transport. Samples were transported, on the day of processing, from the commercial processing facility to the selected supermarkets via refrigerated delivery trucks. Upon arrival, samples were stored in a cold room at 3 °C for four days. The thermally-insulated boxes that contained the samples were refilled with ice, as required, in order to maintain a cold temperature. These boxes were removed from the cold storage facility of the supermarket on the day of testing. A total of 1620 individual packs were tested by the 405 respondents.

5.2.3 In-store consumer test experimental set-up

Supermarket shoppers who came close to the booth set-up, were invited to participate in the DCE and informed consumer sensory test. Willing participants were asked if they ate watermelon and if they had food allergies, as stipulated in the Ethics protocol. They were then informed about the objectives and the detailed instructions of the experiments. A signed consent was obtained from these participants before the session. Human Ethics approval was granted by the University of Tasmania: H0015933.

A total of four hundred and five (n = 405) willing consumer participants joined the DCE and informed consumer sensory test. The participants consisted of 52 % females and 48% males with age ranges of 18-30 years (52 %), 31-40 (19 %), 41-50 (9 %), 51-60 (10 %) and > 60 (10 %). The cultural background was 42 % Asian, 28 % Australian, 20 % European, 5 % Middle Eastern, 2 % African, and 1 % Latin American. These participants were classified as either users (n = 195) or non-users (n = 210) of the existing FCW offering in the market prior to innovation.

The combined intercept-administered DCE, and a subsequent informed consumer tasting, were conducted in four supermarkets in the central business district of metropolitan Sydney, Australia from March to April 2018. A booth was set up close to where FCFs were displayed to perform the DCE and informed consumer tasting (Appendix 5.2). The set-up area was well lit to provide proper lighting during the evaluation of products. During an intercept-survey of five to seven minutes, each participant was asked to choose the FCW prototype that s/he would most likely buy when s/he felt like eating FCW. Each was also asked to provide reason(s) for the selected option. All participants completed nine choice sets. Participants indicated their preference in each choice set presented to them. After completing the DCE, they then indicated hedonic liking for each of the products provided for them and their decision on whether to repurchase these tested products (Table 5.2).

Table 5.2. Integrated DCE and informed consumer sensory test.

Stage		Information available to respondents	Measure elicited
1.	DCE: purchase simulation of FCW formats	Extrinsic product attributes: packaging container shape, presence of mint leaves, POD information in addition to the UBD	Preferred choice
2.	Informed consumer sensory test: consumption of FCW formats	Extrinsic product attributes: packaging container shape, presence of mint leaves, POD information in addition to the UBD Intrinsic product sensory attributes: fresh appearance, colour, smell, firmness of the cubes, taste, flavour and overall liking	Relative hedonic liking: 9-point hedonic scale Purchase intent: binary yes/no

5.2.3.1 Purchase simulation: DCE

Table 5.3. Extrinsic product cues and levels of FCW formats for DCE.

Extrinsic product cue	Level
Mint leaves	FCW without mint leaves (current offering)
	FCW with mint leaves
Packed-on date (POD)	UBD information without POD information (current offering)
	UBD information with POD information
Shape of packaging container	Shaker cup (current offering)
	Square punnet

An intercept-administered DCE, simulating a shelf of FCW, was used to measure the preference of participants based on extrinsic cues. The important extrinsic cues were identified in Phase 2 of the PV innovation model and included different packaging container shapes (square punnet vs. shaker cups), mint leaves (included vs. excluded), and POD information (included vs excluded with the UBD information). The product cues and levels for the DCE are shown in Table 5.3. A total of eight formats of FCW were generated based on a 2^3 experimental design using XLSTAT Version 2019.4.1 (California, USA) as shown in Table 5.1.

The allocation of the FCW formats in the nine choice sets was based on a main-effects design (Wilke et al., 2019) where each extrinsic cue was examined on how it influenced perceived value and preference. The choice sets were randomly and equally assigned to test the influence of each extrinsic cue on the preference of participants for FCW prototypes. To avoid participant fatigue, the choice design was restricted to nine choice sets in total, instead of the 16 choice sets required by balanced complete block design.

A visual representation of the choice sets was provided during the purchase simulation by showing two FCW formats at a time with their retail price and an opt-out alternative. Each shelf or choice set was presented on a laminated A4 size paper, ensuring that all label information was clearly visible. The top labels of the FCW formats were graphically varied to ensure that all FCW displayed the same information in the same font size (ingredients, weight, price and shelf-life information). An example of a choice set is shown in Fig. 5.4.

	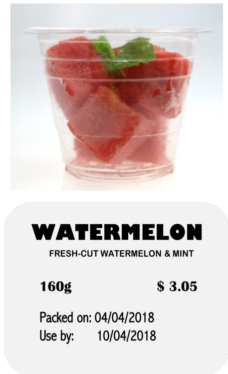	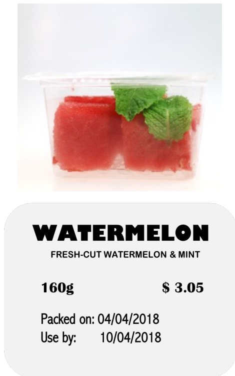	No. I wouldn’t buy any of these products.
Packaging	Cup	Square	
Mint leaves	Yes	Yes	
Packed on date	Yes	Yes	

Fig. 5.4. Example choice set in the questionnaire.

5.2.3.2 Consumption simulation: informed consumer sensory test and repurchase intent

The consumption of the developed FCW formats was simulated in-store by using an informed consumer sensory testing with the set-up described in Section 5.2.3 and shown in Appendix 5.2. Immediately after purchase simulation, the same 405 participants were asked to evaluate the actual FCW formats (Fig. 5.5). Each participant received four out of eight FCW formats in an informed tasting condition, so that 1620 responses per FCW format were obtained. The four FCW formats consisted of samples with and without mint leaves, with and without POD information in either square punnet or shaker cup containers (Table 5.1). The allocation of FCW prototypes was controlled by an incomplete block design.

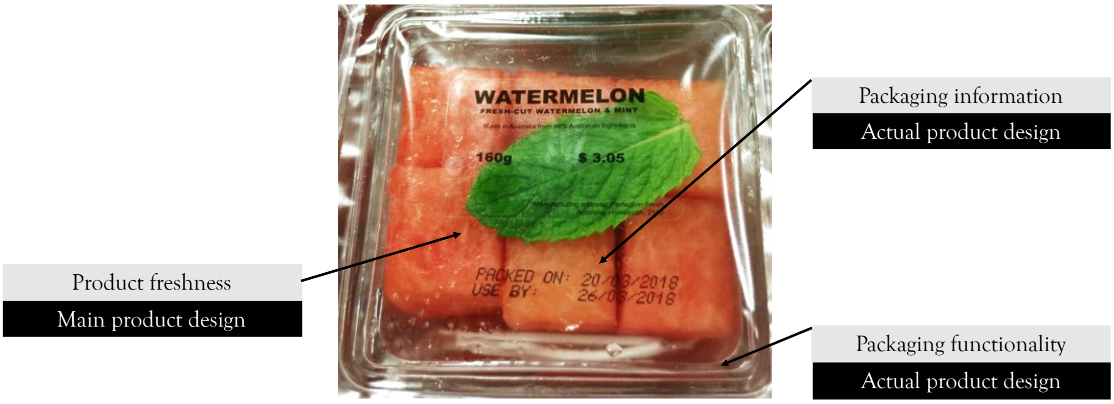

Fig. 5.5. Examples of actual FCW prototype tested in an informed tasting condition.

The informed consumer sensory testing of the FCW formats was carried out in-store following the purchase shelf-simulation tests. The booth was installed under sufficient lighting for proper evaluation of the visual quality of the samples. Individual samples of FCW formats were presented to each participant to evaluate appearance (*colour, fresh appearance*), odour quality (*smell or storage odour*), eating quality (*firmness, taste and flavour*) and overall quality. Instructions to rank each sensory attribute using a 9-point hedonic scale, ranging from *dislike extremely* to *like extremely* were given. Liking scores for the sensory attributes were verbally communicated by each participant and were recorded on the score sheet. Participants had a forced rest of 30 seconds in between evaluating samples. Ranking score for each sensory attribute was verbally provided by the participant and noted by the researcher on the score sheet.

Purchase intent for FCW prototypes was elicited in-store immediately after the consumer sensory testing. Participants were asked to indicate if they would purchase the FCW format they had tested, and the reason for repurchase or otherwise. Repeat purchase intention was measured as a binary choice (yes or no) to approximate a discrete choice used in the first simulated stage of the experiment. Participants were also asked to rank the FCW formats tested from one to four, with one (1) as most preferred and four (4) as least preferred. Score sheets were then collected, encoded and analysed.

5.2.4 Statistical analysis

5.2.4.1 Purchase simulation: analysis of DCE

Discrete choice data from two-options and an opt-out alternative were all encoded and processed in Excel® (Microsoft version 16.33). The data was analysed by first excluding the opt-out choice responses. Excluded opt-out alternative responses were processed by calculating the percentage of participants and treated as potential users of developed FCW formats. Segmentation of participants was determined as the basis for analysing improvement of the perceived value for FCW formats. The segmentation of participants includes initial current users and non-users who would buy: (1) any of the FCW formats presented (2) if only desired product extrinsic cues were in the FCW formats presented, (3) if their suggestions such as use of environmentally friendly packaging, lowering of price and increase in portion size would be considered in the future, and (4) nothing nor any similar products in the future. Responses of those who would buy the FCW formats presented during the purchase shelf-life simulation (Segment 1) were transformed into dummy variable codes and run through a combined binary conditional logit regression model (McFadden and Zarembka, 1974) using SPSS Version 25 in order to determine the influence of extrinsic cues to product choice.

Table 5.4. Example of data set-up for the choice data using dummy variable coding.

ID no.	Choice set	Alternative	Choice	Packaging container		Mint leaves		POD information	
				Cup	Square	With	Without	With	Without
1	1	1	1	1	0	1	0	1	0
1	1	2	0	0	1	0	1	0	1
1	1	3	0	0	0	0	0	0	0
1	2	1	1	1	0	1	0	1	0
1	2	2	0	0	1	0	1	0	1
1	2	3	0	0	0	0	0	0	0

Dummy-variable coding was carried out by coding both the dependent and independent categorical variables of the choice data. The dependent variable refers to the discrete choice coded as one (1) for the alternative that was selected and zero (0) for the alternative that was not chosen in that choice task. Independent variables relate to the attribute levels of each alternative, which were also dummy-coded. The dummy codes used were as follows: formats that used the round cup as the packaging container were coded as one (1) and zero (0) for square punnets; those with mint leaves were coded with one (1), otherwise, zero (0); and those with POD information were coded with one (1), otherwise, (0) (Table 5.4). The choice data generated from the dummy variable coding was set up prior to running in the binary conditional logit model. The set up was done by constructing two rows for each task for each participant and one row for each alternative. A total of 5004 rows were constructed with responses from the 278 participants who selected any of the FCW formats presented and were subjected to a binary conditional logit regression model. The outputs of the logit model were reported and the percentage of preferred FCW formats were estimated to provide projected market share based on the purchase simulation experiment shown in the results section (Section 5.3).

5.2.4.2 Consumption and repurchase decision: analysis of liking and purchase intent

Hedonic data of the developed FCW formats were analysed based on the published protocols of Mendoza-Enano et al. (2019a). The frequency, percentage and ranking of repeat purchase intent for the FCW formats were also reported. All data were encoded in Excel (Microsoft version 16.33). Consumer data was subjected to Kruskal-Wallis nonparametric test in XLSTAT (version 2019.4.1). Reported overall scores were calculated as the average of *liking* scores for appropriate sensory components. Overall appearance *liking* score was calculated from the mean *liking* scores of colour and fresh appearance; overall flavour *liking* score from mean *liking* scores of storage odour, flavour and taste of the cubes; overall quality *liking* score from all sensory components including firmness *liking*. Ranking of preferred FCW formats for repurchase was elicited after the consumer sensory testing. The sum of ranks for each FCW format was computed and was also subjected to a Kruskal-Wallis nonparametric test in XLSTAT (version 2019.4.1) to test for significance.

5.3 Results

The results of the integrated purchase and consumer simulation obtained from 405 participants are structured as follows: Purchase and consumption behaviour, DCE, informed consumer sensory testing and repeat purchase intention.

5.3.1 Purchase and consumption behaviour

Purchase and consumption of developed FCW formats were simulated among current users (n = 195) and non-users (n = 210) who were classified based on their purchase and consumption behaviour for the current market offerings of FCW. Only less than 10 % of the current user participants were frequent buyers and consumers of the existing FCW offerings (Fig. 5.6). Between 10-20 % would purchase and consume these products one to three times a week or a fortnight. Most of them (46 %) would buy and consume FCW one to three times a month and less than 20 % one to three times a year (Fig. 5.7). Upon buying, the users of the current FCW offering would mostly consume the product immediately (Fig. 5.8).

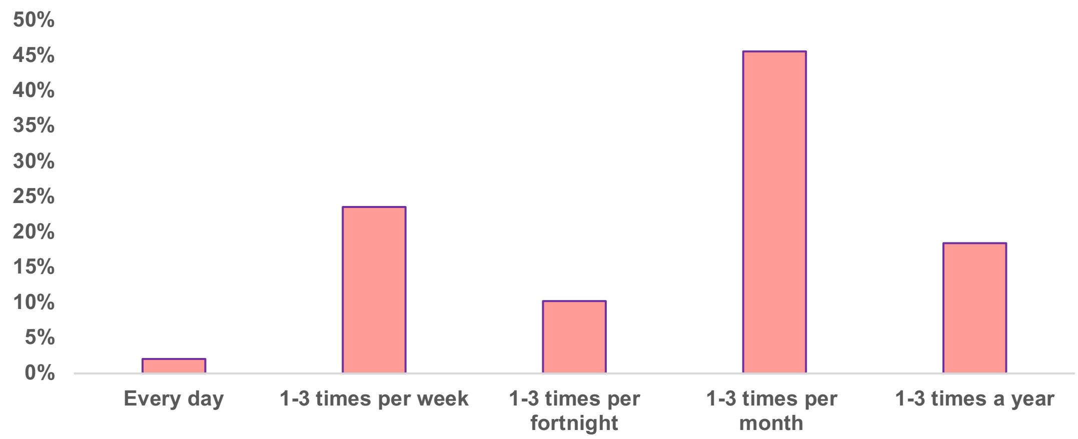

Fig. 5.6. Frequency of purchase among current users of the existing FCW offerings.

Conditions: results were computed based on the users (n=195) of the current commercial offerings.

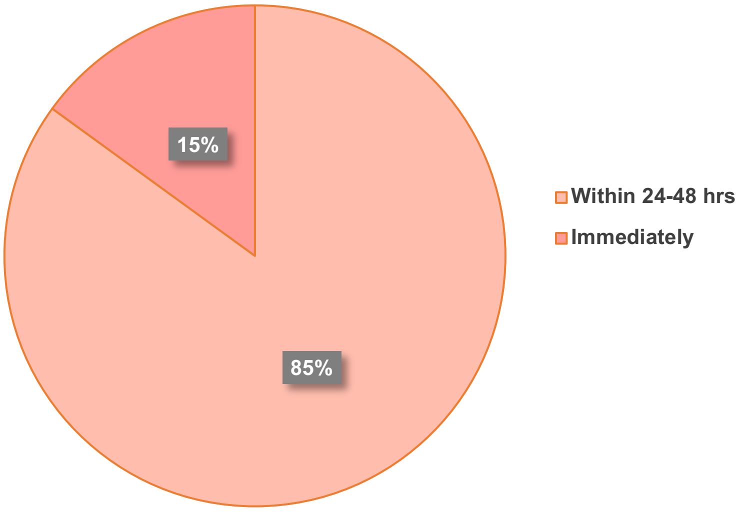

Fig. 5.7. Consumption of FCW after purchase.

Conditions: results were computed based on the number of users (n= 195) of the current offerings.

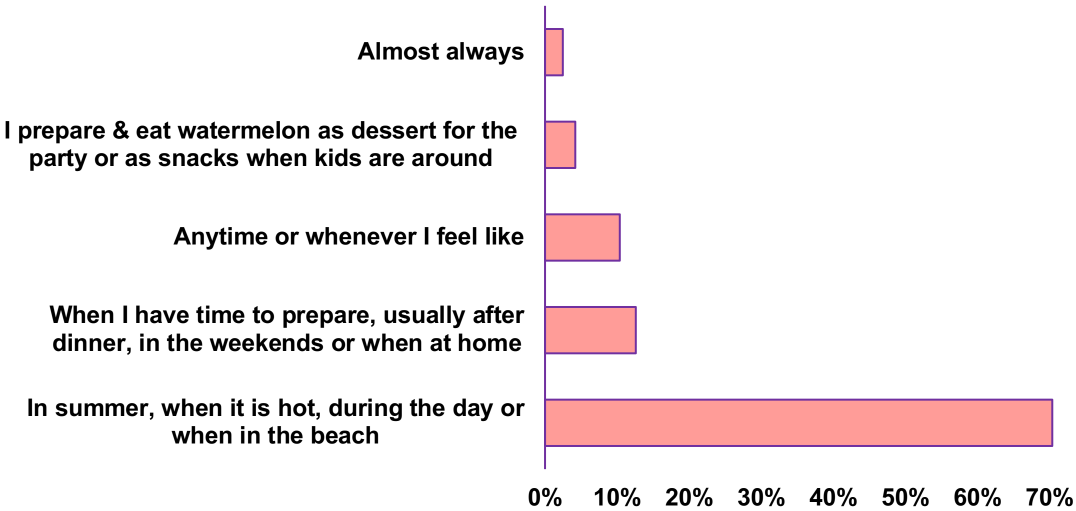

Fig. 5.8. Occasions of purchase and consumption of watermelon.

Conditions: results were computed based on the total number of participants (n= 405).

The participants were asked to imagine these occasions when they would most want to buy and eat watermelon during the purchase simulation of the developed FCW formats (Fig. 5.8). Seventy percent (70 %) would purchase and eat watermelon in summer, or during the day, when the weather was hot and when participants spent time at the beach. Watermelon was also the chosen fruit when these participants had sufficient time to prepare and cut the fruit and during parties. Ten percent (10 %) ate the fruit whenever they felt like it and two per cent (2 %) at all times.

5.3.2 Purchase simulation: product preference

The purchase simulation consisted of 48 % users and 52 % non-users (n= 405) of the current FCW offerings in the market. Out of the users, 94 % indicated their preference for any of the eight developed FCW formats while 73 % of the non-users gave a similar response. The rest selected the opt-out alternative in all the choice sets presented during the DCE. The participants were further segmented in order to analyse the improvement of perceived value for the FCW formats developed from the innovation model.

5.3.2.1 Participant segmentation based on preference

The participants of the purchase simulation were segmented according to their purchase behaviour response during the DCE (Fig. 5.9). The first segment was composed of approximately 70 % of the participants (users = 38 % and non-users = 31 %) who indicated their preference for developed FCW formats presented during purchase simulation. Reasons for preference were attributed to either usage of shaker cups or square punnets to contain the FCW, the presence or absence of mint leaves, and the availability or unavailability of the POD information in the packaging labels. The preference, liking and purchase intent of this group was segregated from the pool of participants in order to determine any deviation of perceived value from purchase to consumption and repeat purchase decision stages. The other participants (30 %) were later distributed to three other segments in order to identify deviation of the perceived value for products during consumption and repeat purchase intent (Fig. 5.9). One segment was composed of 7 % current users and 7 % non-users who would buy any of the FCW formats if important extrinsic cues were available in the alternatives presented (Segment 2). Another segment was composed of participants (5 % current users and 2 % current non-user) who failed to indicate their preference for any of the FCW formats presented to them (Segment 3). However, these participants would be willing to buy in the future provided that their suggestions are incorporated in the product.

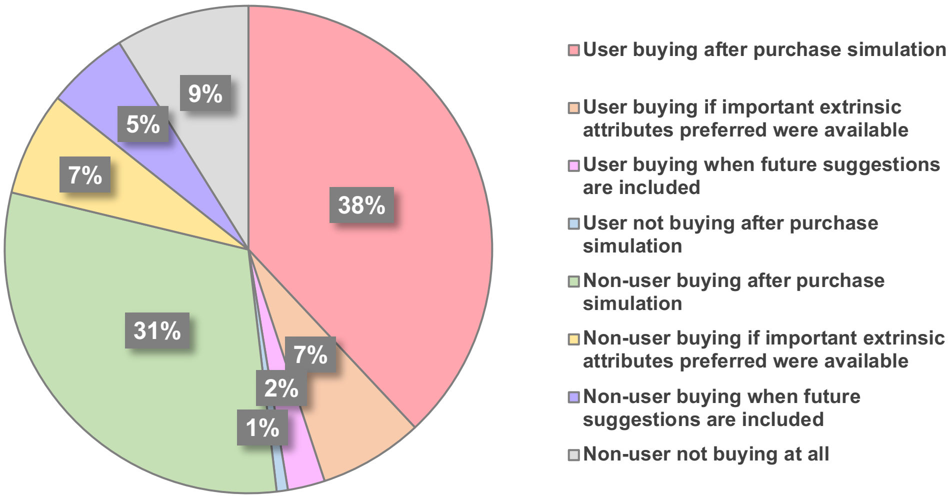

Fig. 5.9. Segmentation of participants based on purchase shelf-life simulation.

Conditions: results were computed based on the total number of participants (n = 405).

These suggestions included: changing the current packaging into an environmentally friendly type, increasing the single portion size from 160 g to 375 g, and cutting the price per portion size from AU$3.00 to AU$2.00. (Fig. 5.9). The last segment consisted of those who would never buy any of the FCW formats presented during the purchase simulation (Segment 4). The participants (9 % current non-users and 1 % current users) who were in this segment selected the opt-out alternative due to the negative perception of safety and freshness of the products and hence, were accustomed to the habit of cutting their own fruit. Regardless of the selection of the opt-out alternative, the participants from these three segments were willing to participate in the consumer sensory test and indicated their purchase intent thereafter.

5.3.2.2 Drivers of product choice based on utilities

A binary conditional logistic regression was performed to ascertain the effects of price, packed-on date information, mint leaves and use of shaker cup in place of a square punnet on the likelihood that participants indicate their preference. The logistic regression logistic model was statistically significant, $\chi^2(4) = 543.262$, $p < 0.000$ (Appendix 5.3). The model explained 14.0 % (Nagelkerke R^2) of the variance in the preference for FCW formats and correctly classified 67.6 % of cases (Appendix 5.3).

Table 5.5. Probability of extrinsic cues influencing choice from conditional logit model.

Product extrinsic cues	*ß*	S.E.	Wald	df	Sig.	Exp*(ß)*
Price	1.790	4.340	.170	1	.680	5.990
Shelf-life information (1)	1.095	.061	319.297	1	.000	2.990
Shape of the packaging container (1)	.943	.066	202.130	1	.000	2.568
Visual cue (1)	.545	.227	5.774	1	.016	1.724
Constant	-6.826	13.021	.275	1	.600	.001

Conditions: shelf-life information: 1 = with POD, 0 = without POD; shape of the packaging container: 1 = cup, 0 = square; visual cue: 1 = with mint leaves, 0 = without mint leaves

Participants were three times more likely to buy FCW formats with an additional POD information and were two and a half times more likely to prefer FCW in cups than in square punnets (Table 5.5). In addition, FCW formats with mint leaves were approximately two times more likely to be chosen than those without the herb. The price, however, was not statistically significant in the preference of FCW formats (Table 5.5).

5.3.2.3 Market share projection

The market shares of the eight developed FCW formats were projected in order to determine which ones would be most likely to sell, once introduced into the market (Fig. 5.10). The projection was based on the responses of the 70 % current users and non-users (Segment 1) who indicated their preference for the FCW formats presented during the purchase simulation. The combination POD information and inclusion of mint leaves in FCW, contained in shaker cups, had the highest projected market share among FCW formats (C_M_POD = 33 %). Next in rank to this FCW format were those with POD information regardless of the presence of mint leaves and shape of the packaging containers (C_P_POD = 22 % and S_M_POD = 15 %). The FCW formats without POD information were the ones with lowest market share (C_P_UBD = 6 %, S_M_UBD = 4 % and S_P_UBD = 2 %).

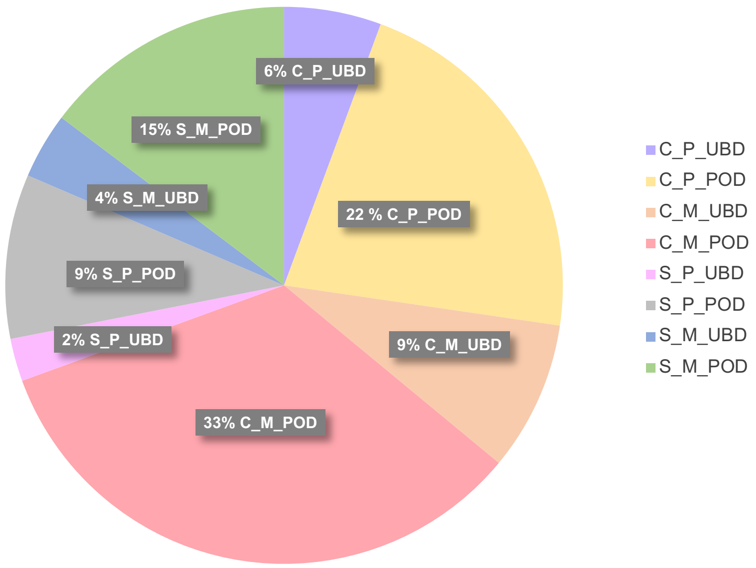

Fig. 5.10. Projected market share of the eight developed FCW formats.

Conditions: C= cup, S = square, M = with mint leaves, P = without mint leaves, POD = with POD, UBD = without POD; Sample signature: C_P_UBD = FCW contained in cup without mint leaves and without POD; % of preference per FCW format from Segment 1 participants (n = 278).

5.3.3 Consumption simulation: informed consumer sensory testing

The informed consumer sensory testing was carried out in order to simulate consumption of developed FCW formats. The consumer sensory liking for developed FCW formats was significantly influenced by the addition of POD, inclusion of mint and shape of the packaging container (Table 5.6). The availability of POD information on the label, in addition to UBD, significantly increased the visual quality, eating quality and overall liking of the products.

Moreover, the liking for colour appeal, fresh appearance, odour, flavour and taste of the FCW formats was positively influenced by the presence of mint leaves. The interaction of both POD information and mint leaves resulted into higher liking for taste, flavour and overall liking of the FCW. The shape of the packaging container, on the other hand, only influenced the liking for the colour and firmness of the watermelon cubes (Table 5.6). Other interactions of the identified extrinsic cues showed insufficient evidence for difference in the liking of developed FCW formats (Appendix 5.4). Significantly different results were also observed in the sensory liking of current users and non-users for individual FCW formats regardless of the segments (Table 5.6).

Table 5.6. Effects of variables in the liking of FCW formats.

	Colour	Fresh appearance	Odour	Firmness	Taste	Flavour	Overall
POD (p = 0.001)							
With	7.7 [a]	7.8 [a]	7.8 [a]	7.9 [a]	7.9 [a]	7.9 [a]	7.9 [a]
Without	7.5 [b]	7.6 [b]	7.6 [b]	7.6 [b]	7.6 [b]	7.6 [b]	7.6 [b]
p-val	0.008	0.002	0.000	0.000	0.000	0.000	0.000
Mint leaves (p= 0.000)							
With	7.7 [a]	7.8 [a]	7.8 [a]	7.8 [a]	7.8 [a]	7.8 [a]	7.8 [a]
Without	7.5 [b]	7.6 [b]	7.6 [b]	7.7 [a]	7.6 [b]	7.6 [b]	7.7 [a]
p-val	0.001	0.001	0.000	0.078	0.045	0.047	0.069
Packaging container shape (p= 0.020)							
Cup	7.5 [a]	7.6 [a]	7.7 [a]	7.6 [a]	7.7 [a]	7.7 [a]	7.7 [a]
Square	7.7 [b]	7.8 [a]	7.8 [a]	7.8 [b]	7.8 [a]	7.8 [a]	7.8 [a]
p-val	0.002	0.051	0.096	0.029	0.185	0.121	0.114
Mint leaves X POD (p= 0.024)							
With ML X with POD	7.8 [a]	7.9 [a]	7.9 [a]	7.9 [a]	7.9 [a]	7.9 [a]	7.9 [a]
With ML X without POD	7.7 [a]	7.8 [a]	7.8 [a]	7.8 [a]	7.8 [a]	7.8 [a]	7.8 [a]
Without ML X with POD	7.7 [a]	7.8 [a]	7.7 [a]	7.9 [a]	7.9 [a]	8.0 [a]	7.9 [a]
Without ML X without POD	7.3 [a]	7.4 [a]	7.4 [a]	7.5 [b]	7.4 [b]	7.4 [b]	7.4 [b]
p-val	0.078	0.086	0.158	0.008	0.007	0.003	0.005
Usage status (p= 0.000)							
Non-user	7.5 [a]	7.5 [a]	7.6 [a]	7.6 [a]	7.6 [a]	7.6 [a]	7.6 [a]
User	7.7 [b]	7.9 [b]	7.8 [b]	7.9 [b]	7.9 [b]	7.9 [b]	7.9 [b]
p-val	0.000	0.000	0.002	0.000	0.000	0.000	0.000

Conditions: Liking scores were based on a 9-point hedonic scale. Means (n= 1620) with different superscripts are significantly different ($p < 0.05$).

The liking for visual quality, odour and flavour quality of the eight developed FCW formats were shown in Fig. 5. 11. Highest liking for all the sensory characteristics of the products was consistently evident in FCW contained in square with mint leaves and added POD information (S_M_POD). The sensory liking for the other five FCW formats was lower. However, it was statistically insignificant. Common among these formats was either the availability of POD or the presence of mint leaves. In the absence of these two extrinsic attributes, the liking for the FCW formats (C_P_UBD and S_P_UBD) was significantly lower (Fig. 5.11).

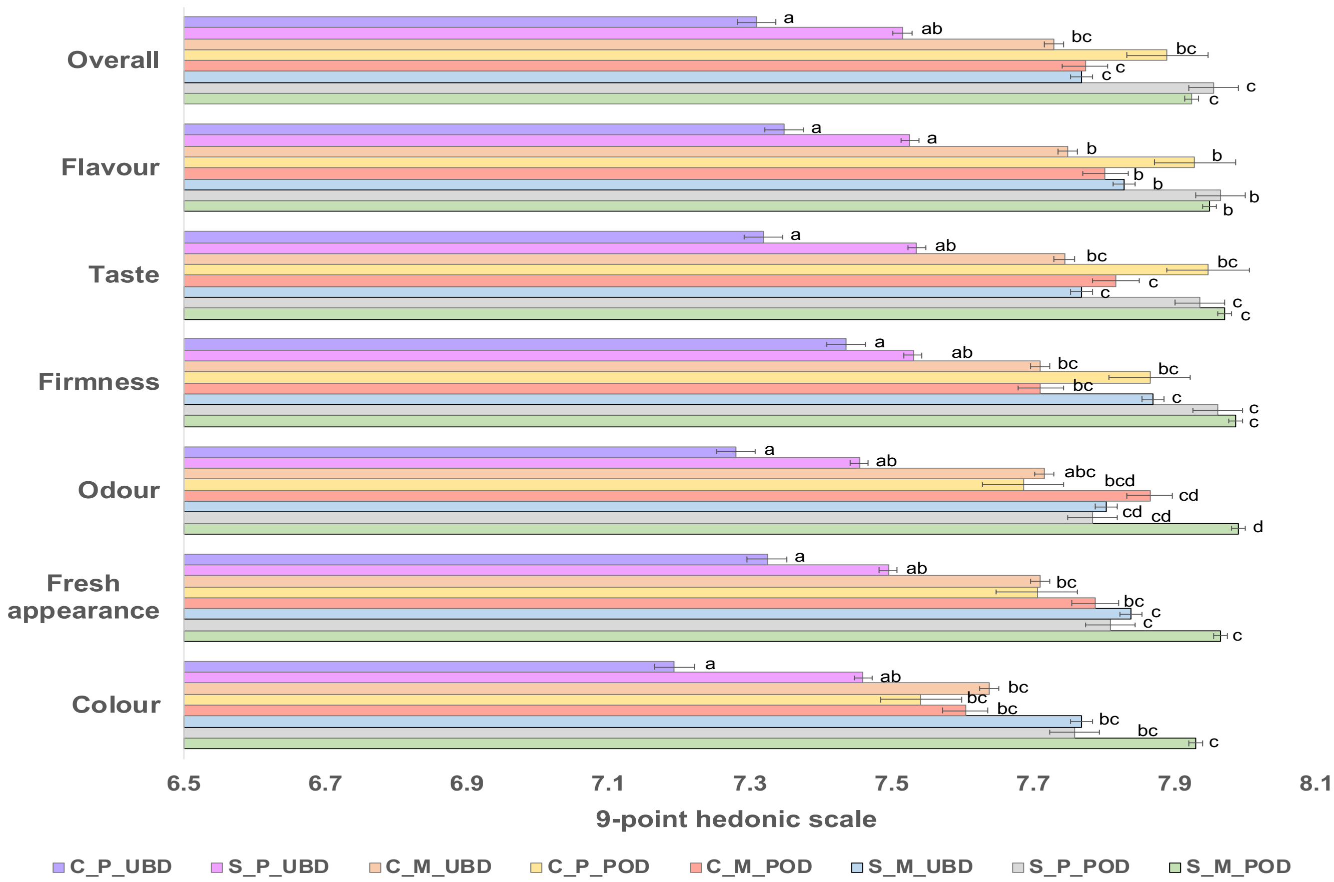

Fig. 5.11. Consumer liking of FCW formats.

Conditions: C= cup, S = square, M = with mint leaves, P = without mint leaves, POD = with POD, UBD = without POD; Sample signature: C_P_UBD = FCW contained in cup without mint leaves and without POD; Mean (n = 405) liking scores using 9-point hedonic scale. Difference in letters indicate significant difference between variables ($p < 0.05$).

5.3.4 Repeat purchase intent simulation

Repeat purchase intention was obtained in order to determine the perceived value improvement for the developed FCW formats after consumer sensory testing. More than half of the participants who were initially non-users of the FCW (70 %), would purchase at least 25 % of the developed FCW formats they had tested (Table 5.7). In contrast, only six per cent (6 %) of the current users would not purchase any of the FCW formats they had tried during the consumer sensory test (Table 5.7). Repeat purchase intent was mainly due to good taste experience, perceived sensory freshness, satisfaction with mint and watermelon combination, confidence in the POD information, contented with the shapes of the packaging container. On the other hand, value for money, and concern for the detrimental effects of plastic packaging on the environment, were the identified deterrents to repeat purchase. Moreover, the perceived risks of product safety, and habit and lifestyle also negatively influenced the repeat purchase intention for the developed FCW formats (Table 5.7)

5.3.4.1 Repeat purchase intention based on participant segmentation

The repeat purchase intent response for the FCW formats gathered after consumer sensory testing was compared to the preference response during purchase simulation. The comparison was carried out among the four segments identified earlier in order to determine the consistency or changes of the perceived value before and after the consumer sensory testing (Table 5.7).

Approximately 90 % of Segment 1 participants (55 % users and 45 % non-users) intended to repeat their purchase for FCW formats after testing the products. This group indicated their preference for all the developed FCW formats during the simulation. Only 10 % (3 % users and 7 % non-users) of this group did not intend to repeat purchase any of the FCW formats tested. Almost the same total percentage of participants in Segment 2 indicated their repeat (91 % = 46 % users + 45 % non-users) and non-repeat purchase intention (9 % = 4 % users + 5 % non-users) for products after consumer sensory testing. This group indicated their preference for any of the developed FCW formats as well as the opt-out alternative during purchase simulation.

Table 5.7. Motivations and deterrents of repeat purchase for developed FCW formats.

	Purchase simulation		Repeat purchase intention after consumption simulation			
Segment	**Initial usage status**	**Preference for developed formats**	**≥ 25 % Repeat purchase of developed formats**	**Example responses of motivations[1]**	**0 % Repeat purchase of developed formats**	**Example responses of deterrents[1]**
1	User	155	149	"It is fresh." "Taste is good." "Taste with mint is nice." "Available POD info is good." "Cup container is convenient." "Square packaging is nicer."	6	"It is expensive." "I am willing to buy if the price is at AU$1.00 - AU$2.00." "Portion size is small for me."
	Non-user	126	105	"It is fresh." "Taste is good." "It is convenient and not heavy." "It is refreshing and gives health benefits." "It quenches thirst and good after eating spicy food." "Taste and smell are fresher with mint." "The mint leaves cool feeling in the mouth." "I like that POD is included." "Packaging container is good."	21	"It is expensive." I am willing to buy if the price is at AU$1.00 - AU$2.00, I am concerned with the usage of plastic packaging that harms the environment, I prefer to cut my own fruit, it is my habit and lifestyle to prepare my own fruit, I will buy only when I do impulse buying."
2	User	28	26	"Taste is nice." "The product is fresher and tastier with mint." "Available POD information is good." "Square packaging is nice."	2	"It is expensive." "I am willing to buy if the price is at AU$2.00."
	Non-user	28	25	"Taste is nice." "Mint inclusion is novel." "It is a nice mint and watermelon combination." "Available POD information is good." "Cup packaging is convenient."	3	"It is expensive." "I am willing to buy if the price is at AU$1.00." "I prefer to eat whole watermelon at home."

Segment	Purchase simulation		Repeat purchase intention after consumption simulation			
	Initial usage status	**Preference for developed formats**	**≥ 25 % Repeat purchase of developed formats**	**Example responses of motivations[1]**	**0 % Repeat purchase of developed formats**	**Example responses of deterrents[1]**
3	User	10	5	"Taste and look are better with mint." "Taste is nice; price is fine." "POD included is good." "Packaging container is good." "Colour is nice and tastes sweet with mint." "It looks fresher with mint."	5	"It is expensive." "I am willing to buy if the price is at AU$1.00 - AU$2.00."
	Non-user	22	6	"Taste is nice." "It is convenient."	16	"It is expensive." "I am willing to buy if the price is at AU$1.00 - AU$2.00." "Portion size is small for me" "I am concerned with the usage of plastic packaging that harms the environment."
4	User	2	2	"It has a fresh taste." "Taste with mint is nice."	0	
	Non-user	34	11	"I like the taste with mint." "Taste is nice." "POD included is good." "Packaging container is good." "The product is quick and easy."	23	"It is expensive." "I am willing to buy if the price is at AU$1.50." "Portion size is small for me." "I am concerned with the usage of plastic." "Packaging that harms the environment." "I prefer to cut my own fruit." "It is my habit and lifestyle to prepare my own fruit." "I have issues with it not being as fresh as the newly cut one."
Total		405	329		76	

[1] Examples were extracted from the most common response.

For Segments 3 and 4, that were mostly composed of initial non-users of FCW formats, between 20 % to 30 % of the participants in these groups indicated their repeat purchase intentions for products tested.

The motivations and deterrents of the four segments to repeat the purchase for the FCW formats tested were identified for consideration in the future product developments. In all four segments, repeat purchase intention was primarily due to satisfaction in the taste experience of the product with or without the mint leaves. Other reasons that influence the repeat purchase intent were POD inclusion and convenient packaging. The same motivation of purchase was observed in both initial users and non-users of FCW formats. Deterrents of repeat purchase among the participants, however, were slightly different. Price was a determining factor of "no repeat purchase" among the non-users. Moreover, the habit of buying whole watermelon and cut the fruit themselves also significantly affected their decision not to repeat their purchase for the products tested. This group strongly perceived the risks in food handling and safety, as well as maintaining the freshness of the fruit once it is cut and hence, would still prefer to prepare their own fruit. The decision "not to repeat purchase" among the initial users of the FCW was also highly influenced by the price per portion of the product. In addition, the size of each portion was relatively smaller compared to their consumption of FCW and hence the FCW formats were perceived as low value for their money (Table 5.7).

5.3.4.2 Repeat purchase intention for FCW formats

The ranking of repeat purchase intention for the developed FCW formats were determined in order to focus industry efforts for commercialisation. The FCW with fresh visible mint leaves and POD information that was contained in either square punnet (S_M_POD) or shaker cup (C_M_POD) received the highest number of repeat purchase intention (Fig. 5.12). The FCW formats that were most similar to the current offering (C_P_UBD and S_P_UBD) received the least number of repeat purchase intention among all the FCW formats presented for consumer sensory testing. FCW formats that fell in between the highest and least ranks included C_P_POD, S_P_POD, C_M_UBD and S_M_UBD (Fig. 5.12).

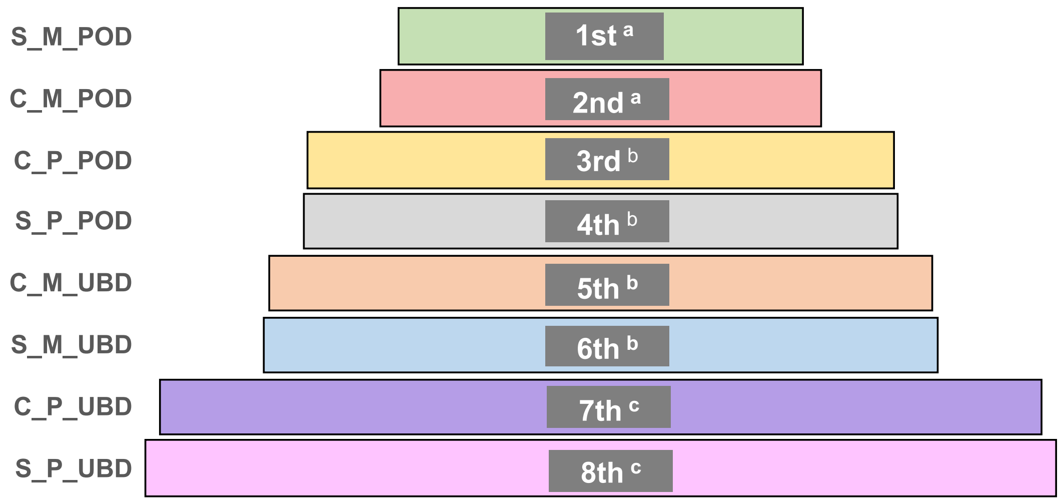

Fig. 5.12. Likelihood of repeat purchase preference for developed FCW prototypes.

Conditions: C= cup, S = square, M = with mint leaves, P = without mint leaves, POD = with POD, UBD = without POD; Sample signature: C_P_UBD = FCW contained in cup without mint leaves and without POD; Rank is based on mean of rank scores. Difference in letters indicates significant difference between FCW formats (p <0.05).

5.4 Discussion

This research was to test the effectiveness of the PVI model for FCFs. This was achieved through the implementation of the final phase of the innovation model, that is, the testing of the improvement in the perceived value of FCFs developed at the earlier phases of the model. An integration of purchase and consumption stages was simulated using the DCE and informed consumer sensory test in a retail market scenario. The experimental set-up close to the display of FCFs in the supermarkets provided an ambiance of how buyers would select the products that they buy from retail shelves. The simulations were carried out as a prospective buyer would choose a product from the retail shelf without tasting it as s/he could not taste the product. S/he would then later assess how much s/he liked the product and decide if s/he would repurchase it. These methods were tested in order to assess the appropriateness in measuring the perceived value improvement of FCFs.

In addition, the research was to determine the improvement of the perceived value for the FCW formats developed from the innovation model. Both users and non-users of the current FCW commercial offerings were included in order to confirm product acceptability of the developed formats to a wider population and gauge a potential target market, respectively.

5.4.1 Applicability of purchase and consumption simulations to the PVI model

5.4.1.1 Applicability of DCE and the construction of choice sets

The DCE was first carried out in order to simulate purchase of FCW formats as closely as possible to a retail market scenario. DCE is an established method for preference elicitation (Campbell and Erdem, 2018). In this study, the participants were presented with nine choice sets in total with two FCW formats and an opt-out alternative to choose from. The nine choice sets were derived from eight choice sets based on a 2^3 experimental design and another choice set that assesses consistency of response behaviour (Wilke et al., 2019). There is no agreement in the literature on the number of choice tasks to be presented in a choice experiment (Louviere et al., 2010). The respondents in this experiment were not given more than nine choice tasks, in order to avoid fatigue and thus start picking randomly among choices rather than based on their preference. The opt-out alternative was provided in each choice set in order to make the choice more realistic (Haaijer et al., 2001). The implementation of DCE in this way allowed for the determination of the improvement in the perceived value of the developed FCW formats when displayed in the supermarkets.

5.4.1.2 DCE data handling and analysis

DCE in this study was used to determine whether the extrinsic cues, such as POD, mint leaves and packaging shape, influence a product choice. The DCE was analysed using the binary conditional logit model. This model is a combination of the normal binary logit regression model and conditional logit model. The binary logit regression model is appropriate for dichotomous variables, both independent and dependent which was the case in this study. The independent variables in the model were the presence of POD information (with or without POD), inclusion of mint leaves (with or without mint leaves) and shape of the packaging container (cup or square). The binary yes or no preference, on the other hand, was the dependent variable. Moreover, the conditional logit model was appropriate for determining the effects of product factors rather than consumer characteristics such as age, gender or cultural background on product choice. This study was limited to determining the influence of extrinsic cues of FCW formats and hence, the conditional logit model applies.

The steps undertaken for the DCE in this study, where the aim was to estimate the willingness to pay for specific FCW formats, were uncommon compared to the usual DCE experiment (Baselice et al., 2017). The DCE data in this study, therefore, was treated differently. DCE data was analysed by first extracting the opt-out alternative responses and running the choice data of product preference in a binary conditional logit model. This approach allowed for the determination of the influence of the extrinsic cues on product preference, and, therefore, the perceived value for developed FCW formats. In addition, the reason for the selection of each preference per choice set was also elicited in order to capture factors in the future which were not included in the variables tested in the present DCE.

5.4.1.3 Applicability of the informed consumer sensory testing

An informed consumer sensory test was carried out in order to simulate the consumption of FCW formats and determine changes in the perceived value of the products after testing. The consumer sensory test followed after DCE, as one would consume convenience products such as FCW and other FCFs right after purchase or within the day of purchase (Fig. 5.7). Informed consumer sensory testing was selected over blind testing in order to mimic how consumers would assess products bought. The end-users are almost always conscious of the extrinsic characteristics when actually consuming the product; that is, they are informed about the origin, price and packaging. Information given to consumers affects product preference and acceptability, based on sensory properties, even before the consumer tests the product (Deliza et al., 1996). Pre-tasting expectations are formed through information such as the packaging label, and the main food product seen through a transparent packaging. A positive or negative disconfirmation arises when expectations are unmet during the actual experience of the product (Carlsmith and Aronson, 1963). Positive disconfirmation results from superseding expectations while negative disconfirmation happens when product performance is worse than expected (Olson and Dover, 1978).

5.4.1.4 Handling of samples for the informed consumer sensory testing

A total of 405 replicate samples per treatment (Table 5.1) were prepared each week (for four consecutive weeks) in order to gather sufficient data in determining the perceived value improvement during consumer simulation. The samples were reduced to ~160 g compared to those used previously (~200 g, Chapter 4) in order to provide sufficient samples for a larger population in this study. Each participant was limited to evaluating four FCW formats, instead of eight, to prevent sensory fatigue. However, this was still sufficient for comparison of preference for the FCW formats.

5.4.1.5 Data handling for the informed consumer sensory testing

In the informed consumer sensory test, the consumer panellists used the 9-point hedonic scale in order to evaluate their liking for the FCW formats. Consumer sensory testing using this hedonic scale is appropriate for consumer panellists, as this test does not require training on complex tasks as with sensory panellists. The instructions in this test were easy to follow such that consumer panellists were not required to compare liking between samples. Instead, they were tasked to individually indicate their liking scores for each product. The recorded liking scores for the products were run in a non-parametric test, which allowed for the comparison of product acceptability. High overall product liking scores meant that there was an increase in the perceived sensory freshness and product acceptability of FCW formats, and therefore improvement in the perceived value. In addition, a multivariate analysis was performed using the liking scores in order to identify the extrinsic cues that significantly influenced the product acceptability. Given these benefits, an informed consumer sensory test using the 9-point hedonic scale was therefore an appropriate approach to simulate the consumption of FCW formats.

5.4.1.6 Applicability of repeat purchase elicitation

Repeat purchase intention was elicited after the consumer sensory test in order to determine the perceived value for the products tested and identify deviation from the purchase simulation. Binary yes or no data were obtained from asking participants whether they had the intention to repeat their purchase for the products they tested. Purchase intent is a response measure for repurchase decision, which is a common measure in sensory consumer research (Di Monaco et al., 2004) and closer in style to a market choice (Mueller et al., 2010). A follow-up ranking of repeat purchase intention for the products tested was also asked thereafter in order to determine changes in the perceived value from the purchase simulation. The FC company would need to understand the reasons for the deviation of perceived value in order to focus on improving product elements during product development (Amini et al., 2014).

5.4.2 Relevance of the model as applied to FCW

The integrated approach allowed for determining the improvement in the perceived value of the different segments of participants for the FCW formats at different stages. The participants who consistently selected any of the developed FCW formats composed Segment 1, while those who selected at least one opt-out alternative fell under Segment 2 (Fig. 5.9 and Table 5.7). The participants who selected either developed FCW formats or the opt-out alternative, were classified under Segment 2. Segments 3 and 4 consisted of participants who only chose the opt-out alternative, however, differed in their reasons for their selection. Segment 3 was composed of participants who would only buy FCW formats if their future suggestions such as a decrease in price and use of environmentally-friendly packaging were incorporated. Participants in Segment 4 were those who would not buy any of the FCW formats due to habit and lifestyle of cutting their own fruit and issues of freshness and food safety (Fig. 5.9 and Table 5.7).

5.4.2.1 PV improvement at different stages of purchase and consumption simulation

The perceived value of the participants in Segments 1 and 2 for FCW was assessed before and after consumer sensory testing in order to determine changes in the perceived value for FCW. Overall, the perceived value of the participants in these segments improved significantly during purchase simulation. Around half of each of Segments 1 and 2 (Table 5.7) initially had never bought the current FCW offering in the retail market prior to DCE and thus, were classified as non-users. These participants, however, were interested to try the FCW formats and thus indicated their preference regardless of the presence of the opt-out alternative in all the nine choice sets. The perceived value of the non-users in Segment 1 and 2 for the developed FCW formats, therefore, improved from their initial perception of the FCW. After consumer sensory testing, 84 % (130 out of 154) of these non-user participants indicated their willingness to repeat their purchase for the developed FCW formats (Table 5.7). This means that satisfaction was achieved during testing, which resulted in higher repeat purchase intention and, therefore, the perceived value for the developed FCW formats was retained. The perceived value of the current users in Segments 1 and 2 was also improved during purchase simulation, as indicated by the higher preference for developed FCW formats compared to the sample closest to the current offering (C_P_UBD). Approximately 96 % (175 out of 183) of these users also retained their perceived value of the FCW formats after consumer testing. In contrast, approximately ten per cent (9.5 %) in these segments decreased their perceived value for the products after testing (Table 5.7).

The same assessment in the perceived value of Segments 3 and 4 participants was performed before and after consumer sensory testing of FCW in order to determine perceived value deviation. These segments were largely composed of non-users (82 %) of the current FCW offering. Their perceived value for the FCW was not influenced by the changes made in the developed formats during purchase simulation. However, 30 % of these participants improved their perceived value of the developed FCW formats after the consumer sensory testing because of the taste and freshness of FCW with mint (Table 5.7). The users in Segments 3 and 4 were mostly familiar with the current FCW offering, however, they only buy the product occasionally (between 1-3 times a month or a year in Fig. 5.6). Their perceived value for developed formats during purchase simulation is rather low due to expensive price and usage of plastic packaging. After the consumer sensory testing, 58 % of these current users improved their perceived value for the developed FCW formats due to taste and freshness in the presence of mint (Table 5.7).

Overall, the perceived value of 83 % of the total participants for the developed formats of FCW was improved during purchase simulation. The preference of both initial users and non-users was higher for the developed formats than the sample closest to the current commercial offering of FCW (C_P_UBD). The perceived value of 81 % of the total participants was retained as indicated by the repeat purchase information elicited after the consumption simulation (Table 5.7).

5.4.2.2 Motivations to purchase and repeat purchase

The motivations for purchase and repeat purchase were elicited in order for the FC company to focus on these product elements for commercialisation of the developed FCW formats. The consumer evaluates the experienced quality. This is influenced by the existing quality expectations formed by the extrinsic cues and actual experience of the sensory characteristics of the product (Mueller et al., 2010). The addition of POD in the shelf-life information positively influenced the product choice of participants (Table. 5.5). POD information also improved the overall liking of FCW formats ($p < 0.05$ in Table 5.6) and influenced the repeat purchase intention of participants positively (Table 5.7). Consumers check the expiration dates frequently, especially for products that deteriorate faster as in FCFs (Van Boxstael et al., 2014). The study of Stranieri and Baldi (2017) showed that most consumers had a negative attitude towards extension of the shelf-life date, as it indicates loss of freshness. The shelf-life date of FCW is referred to as the use-by date (UBD). It is mandatorily displayed on all the current offerings tested in this study. In contrast, the provision of POD information in this study, in addition to the UBD, promoted trust and confidence of the participants towards the FCW. The additional information assisted the participants in gauging product freshness for themselves. For industrial application, POD information may be added to the current UBD to positively impact consumers of FCW and other FCFs.

5.4.2.2.1 Impact of mint leaves as an extrinsic cue

The inclusion of mint leaves as a visual cue was also tested for the improvement of the perceived value of the FCW formats. Results indicated that this cue significantly improved the perception of freshness during the simulation of purchase and consumption. The herb enhanced the visual perception of freshness and natural image of FCW which were critical to the preference for FCW (Table 5.5). Ninety percent (90 %) of the participants were also mint likers and perceived mint to enhance the liking for colour, fresh appearance, pleasant smell, flavour and overall liking of FCW formats during consumer test (Table 5.6 and Fig. 5.10). Nonetheless, FCW without mint leaves should still be produced for consumers who are mint dislikers and would prefer the pure taste of watermelon. The presence of mint leaves also positively influenced ($p < 0.05$) the repeat purchase intent for FCW formats (Table 5.7). Moreover, mint leaves in FCW formats served as an additional indicator of product freshness in the absence of POD and hence were a significant factor for repeat purchase decision (Table 5.7). For industry application, the fresh appearance and intact quality of the mint leaves must be maintained to ensure the perceived sensory freshness of FCW. Overall incorporating mint leaves added value to FCW formats.

5.4.2.2.2 Impact of container shape

In addition to POD and mint leaves, the shape of the packaging container was also tested for improvement in the perceived value of FCW formats during the DCE and consumer sensory test. Container shape affects preference, choice and post-consumption satisfaction (Raghubir and Krishna, 1999). These results showed that this extrinsic cue had significantly influenced product preference during purchase simulation (Table 5.5) and liking for the colour and firmness of the FCW during the consumption simulation (Table 5.6). DCE results revealed that the probability of choice for FCW formats was higher when shaker cups were utilised rather than the square punnets (Table 5.5). The cup format was preferred over the square punnet due to a perception of larger volume based on photos shown during purchase simulation. This result also confirmed the study of Raghubir and Krishna (1999) whose findings showed that taller shapes are perceived as larger than shorter ones, as in the cups and square punnets presented during DCE. Actual samples should therefore be shown during purchase simulation when variables relate to volume such as container shapes and product weights.

The positive influence of cups to FCW formats during purchase simulation, however, was not translated to higher liking for FCW formats during the informed consumer sensory test. The liking for the colour and firmness of the watermelon cubes was significantly higher when square punnets were used than when FCW were contained in cups (Table 5.6). The square punnet provided a neat arrangement with cubes evenly distributed across the square surface, resulting in enhanced visibility of the even bright red colour of the cubes. Moreover, this arrangement of the cubes in the square packaging lessened the amount of interaction between the cubes during handling and distribution resulting in less damage and more intact cubes. This reason was obtained from eliciting the repeat purchase decision and hence was a significant factor for repeat purchase intent. For industry application, the use of square punnets for FCW cubes is therefore recommended to maintain the quality of cubes from processing to storage and retail distribution.

5.4.2.2.3 Impact of sensory cues

The sensory characteristics, as the intrinsic cues of the FCW formats, were also tested in order to determine improvement in product acceptability and therefore perceived value. Such sensory characteristics included colour, fresh appearance, odour, firmness, flavour and taste. The consumer sensory testing, together with the DCE, were carried out for four days per week for four weeks in order to gather sufficient data by using 405 participants. The tests were limited to only 25 participants per day, due to time constraints in the supermarket set-up, and the proportion of prospective of the participants willing to perform the tests. As a consequence, samples given out for consumer sensory testing were stored at 3 °C for up to four days. Prior to the consumer tests, long-stored samples were tested for volatile aromas in order to detect any changes in the volatile profile that would indicate loss of freshness. The results indicated that a four-day stored sample had no significant changes in the volatile profile and concentration compared to a sample stored for one day (Appendix 5.5). Thus, the liking scores across days in between samples were comparable.

5.4.2.3 Deterrents to purchase and repeat purchase

The deterrents for purchase and repeat purchase were elicited in order for the FC company to consider these in future product developments. The deterrents of purchase and repeat purchase were not directly related to the perceived sensory freshness of the products, but were about pricing, portion size and concern for the usage of plastic packaging (Table 5.7). The pricing of each product format was based on the production cost and profit, as well as the pricing of the current FCW offering in the market which was at AU$3.00. The FCW formats tested in this study were priced at AU$3.00 and AU$3.05 for those without and with mint leaves, respectively. The price factor was not statistically significant for Segment 1 participants who indicated their preference for the FCW formats (Table 5.5). It was, however, a determinant of non-repurchase for 10 % of the participants belonging to Segment 1.

For industry application, however, the pricing could be reviewed and adjusted based on the price point sensitivity of the current and potential users of FCW formats. In addition, the price information could be used as a variable in future DCE in order to determine the willingness to pay and pricing strategy for the target market. Portion size on the other hand, had been adjusted in order to provide sufficient volume for all the participants for testing. Thus, the FC company could retain the current commercial size of 220 g instead of 160 g presented during consumer sensory testing. The usage of alternative plastic packaging, such as biodegradable and resealable packaging material, should also be explored in order to encourage environmentally-conscious consumers to buy FCFs such as FCW.

Other deterrents to purchase and repeat purchase included habit and lifestyle of cutting or preparing their own fruit. These are related to risk perceptions of food safety and quality. In this case, the FC company would be recommended to focus on selling the developed FCW formats to the existing user market.

5.4.2.4 Most preferred FCW formats for commercialisation

The market share of the developed FCW formats during purchase simulation was estimated, and their preference ranking was elicited, after consumption in order to identify formats to focus on for commercialisation. The FCW format with mint leaves and POD information contained in shaker cups (C_M_POD) was highly preferred during purchase simulation (Fig. 5.10). This FCW format was also ranked higher among all the other formats except for those contained in square punnets (S_M_POD), which was ranked first after consumption simulation. Nonetheless, statistical analysis showed that there was insufficient evidence to indicate that their rankings were significantly different (Fig. 5.12). For industry application, however, the commercialisation of S_M_POD is recommended as the square packaging allows for maintaining intact watermelon cubes during handling and distribution. It can be noted that all the samples in this study were directly transported from the factory to the site of experiment. In actual production and distribution FCW products are normally first sent to the supermarket distribution centre, and stored for one to two days before distribution to the retail supermarkets. Thus, the use of square packaging is recommended to help maintain the quality of the products over longer travel distances and time of handling and distribution.

5.5 Conclusions

The PVI model for FCFs was effective in yielding FCFs with improved perceived value. The simulated testing results for the innovations of the FCW formats developed from the earlier phases of the model have validated the effectiveness of the model. Therefore, the simulation of purchase and consumption in the testing phase of the PV approach, using a combination of DCE and informed consumer sensory testing, can effectively assess the improvement of the perceived value of developed FCW formats.

The increased preference, product acceptability and repeat purchase for the developed FCW formats indicated a strong evidence of improved perceived value. The extrinsic cues of the FCW, such as the addition of POD, inclusion of mint leaves and varying shape of the packaging container, have resulted in increased preference and product acceptability. The perceived sensory freshness improved through the prior technical innovations (Chapter 4) have also led to increased product acceptability and repeat purchase intent. Therefore, the perceived value for the developed FCW formats has improved.

Chapter 6 Industrial applications of the PVI model

This concluding Chapter integrates the contributions of the research Chapters 3, 4 and 5 in order to address the core research question of the thesis: *Is the PVI model effective in developing commercially-produced FCFs with improved perceived value?* This Chapter also provides recommendations for the industrial applications of the PVI model and highlights the practical outcomes and limitations of the model implementation.

6.1 PVI model development and application

The PVI model was developed from the integration of market and technical innovations for FCF innovation in order to develop better approaches to deliver consumer-effective FCFs. The combined concepts of perceived value, cue utilisation theory and the quality guidance model were used to develop the different phases of the model. The PVI model is therefore composed of three phases linked together by the outputs of each phase, which were utilised as inputs of the next, in order to produce user-oriented FCFs (Fig. 2.8).

The idea generation phase (Fig. 3.1 or Phase 1 of Fig. 2.8) is the first phase of the PVI model and was used to guide the innovation of FCFs based on consumer perceptions. The implementation of this phase with the FC industry addressed the SRQ1: *Can consumer information derived from the idea generation phase of the PV approach be used to produce user-oriented FCFs?* This phase was applied by eliciting from consumers their value perceptions and related product cues influencing the purchase and non-purchase of FCFs. The product cues included both intrinsic and extrinsic cues that were important in the purchase, consumption and repeat purchase intent. Both current and potential end-users were involved in this phase in order to ensure satisfaction of existing customers and, at the same time, to expand the current market. Consumer surveys with BWS were carried out in order to identify determinants and deterrents of FCF purchase. Additionally, in-depth interviews with individuals or mini groups were performed in order to determine the value perceptions and related product cues of FCW as the model test sample of FCFs. The product cues that mostly influenced the perceived value and purchase of FCW were associated to freshness and convenience. These were linked to product components in order to focus product innovation and improve the perceived value of the existing FCW format (Fig. 3.14). This consumer information, derived from the idea generation phase, was therefore the foundation of the FCF innovation process. The outputs of the implementation of Phase 1 were then utilised in the technical innovation phase (Fig. 4.1 or Phase 2 of Fig. 2.8) and market testing phase (Fig. 5.1 or Phase 3 of Fig. 2.8) of the PVI model.

The technical innovation phase (Phase 2, Fig. 4.1), is where different prototypes are developed and tested in order to produce improved FCFs. The implementation of this phase to FC industry addressed the SRQ2: *Can industry-appropriate postharvest techniques and a research tool that combines the subjective and objective measurements improve the perceived value of FCW in the technical innovation phase of the model?* The development of approaches to produce improved FCF prototypes contributed to the evolution and validation of the PVI model. The improved FCF prototypes were designed to have an improved perceived freshness and shelf-life. These prototypes were produced from selection of postharvest processing and packaging techniques. The effects of the postharvest techniques were measured subjectively and objectively (Fig. 4.1). Subjective measurements were performed by small-scale consumers test using the in-house panel of the partner industry. Objective measurements were carried out using analytical instruments to monitor changes in the volatile aroma profile of the FCFs. The results of the consumer tests and volatile measurements, together helped show the effects of postharvest techniques on the quality of the new FCFs (Fig. 4.4). The FCF prototypes produced from the innovation cycles (ICs) had improved the perceived freshness and gave a sensory shelf-life extension from six to eight days (Tables 4.3 to 4.6). The improved prototypes were packaged with an added POD and with changed packaging shape. These were both identified as important extrinsic product cues from Phase 1 implementation (Fig. 3.14). The developed FCF formats were then tested in the last phase of the PVI model.

The market testing phase of the PVI model (Fig. 5.1) was implemented in order to validate the effectiveness of the model. The implementation of this phase to FC industry addressed the SRQ3: *Can simulation of purchase and consumption in the testing phase of the PV approach, using a combination of DCE and informed consumer sensory test, effectively assess the improvement of the PV of developed FCW formats?* Thus, this phase was applied using simulation experiments of purchase and consumption. DCE and informed consumer testing were carried out, respectively, in order to determine the improvement in the perceived value of the actual developed products at purchase, during and after consumption (Figs. 5.10 to 5.12). The FCF formats with improved perceived value were identified as those packed in either square and cup packaging with mint leaves and addition of POD.

The development of these FCF formats with improved perceived value was therefore the overall outcome of the implementation of the phases of the PVI model (Figs. 3.1, 4.1 and 5.1).

6.2 Industrial outcomes of the model achieved as applied to FCW

An adaptation of the improved FCF format was subsequently used commercially by the industry partner for a market launch. Most of the recommendations of the PVI model were implemented by the partner industry for the new format. These recommendations included changes in the processing and packaging. Post-cut sanitation spray was removed and has shown a positive effect to the retention of flavour and taste and reduction of damage to the cubes. Mint leaves were also included in order to increase the perceived freshness and sensory shelf-life of the FCW. Additionally, the lidding film was changed to non-perforated to limit large changes in the atmospheric condition of the packaging for FCW. Packaging containers from cup-shaped were also changed into square punnet. This developed FCW format (Fig. 6.1) launched in the Australian market in March 2019.

A significant positive impact in FCW sales for the company was observed from AU$ 68,124.00 in 2017 to AU$ 400,352.29 in 2019 after the results from the model development were applied (Personal communications from the company, Appendix 6.1). Consequently, end-users have experienced FCFs with improved perceived

Fig. 6.1. FCW and mint sold in the Australian market.

Note: Developed FCF format from the PVI model implementation was sold from March 2019 in main cities of Australia: Sydney, Melbourne, Adelaide and Brisbane.

value in the market (Appendix 6.2). The PVI model was therefore effective in developing commercially-produced FCFs with degree of improved perceived value pending from longer term sales data.

6.3 Applications specific for FCW improvement

The technical innovation experiments in Phase 2 have shown improvement of FCW prototypes in terms of perceived freshness and sensory shelf-life. The effects of MAP on consumer liking and volatile compounds were tested in order to determine the packaging conditions that best promotes higher perceived sensory freshness and extension of sensory shelf-life. While the product development direction of the FC company supported the use of MAP, research findings showed that detrimental impacts to the sensory quality of FCW occurred with the existing packaging (Table 4.3). FCW packed in MAP using polyethylene plastic tubs and lidding films exhibited low consumer acceptability for the use of either perforated or non-perforated films. This finding was contrary to the expected improvements from the use of MAP packaging. Lowering of oxygen and increasing carbon dioxide in the gas atmospheres decreased respiration and improved microbiological quality on FCF storage in various studies (Caleb et al., 2013; Rojas-Graü et al., 2009; Zhang et al., 2015). The adverse finding for MAP use in FCW sensory quality may be due to the physiological nature of watermelon. It may have low tolerance to changes in O_2 and CO_2 levels because of its thick rind that is a barrier to rapid gas exchange. Leaving the rind on could delay senescence of FCW presumably by decreasing the oxygen stress of exposing all the mesocarp directly to atmospheric oxygen levels (Petrou et al., 2013). Post-climacteric fruits, such as the watermelon, may be less tolerant to low O_2 levels and have lower capacity for recovery (Kader, 2001). Moreover, the perforations in the lidding film enhanced the loss of volatile flavour causing organoleptic deterioration (Del-Valle et al., 2004). MAP application on FCW, especially with this packaging condition, is therefore not advised. On the other hand, the packaging process of using ambient air, but with non-perforated lidding film, showed higher consumer acceptability. This may be due to less drastic headspace atmospheric concentration changes as well as retention of volatile flavours. In addition to packaging conditions, the storage temperature has to be maintained at ~3 °C. This is in the current process in order to preserve the quality and prevent the headspace oxygen level falling below the critical limit of 14 % for FCW (Fonseca et al., 2004). With recommended packaging and storage conditions, the sensory shelf-life of FCW was extended up to 8 d. The extension of sensory shelf-life by 20 % can have a significant positive implication on the distribution of products from the commercial facility to distribution centre and to the retail supermarkets.

The perceived freshness and sensory shelf-life of FCW was further improved when the post-cut sanitation spray was removed in the processing step (Table 4.6). Evidence has shown low product acceptability of FCW, especially in terms of flavour and taste, as compared to FCW without the post-cut sanitation spray. Low product acceptability was confirmed by the decreased concentration of headspace compounds associated to freshness and decrease in % TSS. FCW without the post-cut sanitation spray, packed with ambient air, sealed with non-perforated lidding film and stored at ~3 °C for 8 d had better taste, flavour and overall quality than the current offering (Appendix 3.1). The removal of the post-cut sanitation spray step was therefore recommended, in addition to the packaging conditions recommended in the first IC.

The inclusion of visible mint was also investigated in order to enhance the flavour and perceived sensory freshness of FCW. Adding a specific perceptual feature related to freshness, like the visible mint leaves, has led to an enhanced perceived sensory freshness and improved sensory shelf-life (Table 4.5). Evidence has shown that the presence of visible mint leaves improved the visual, flavour and overall liking of FCW prepared using the recommended conditions and stored at ~3 °C for 8 d. Therefore, the inclusion of mint leaves in FCW was also recommended on top of the previous recommendations in the first and second ICs.

The results of the marketing test in Phase 3 of the PVI model showed improvement in the perceived value of the new FCW formats. Product with POD information and mint leaves in square punnets showed higher preference, product acceptability and repeat purchase intent (Figs. 5.10 to 5.12) compared to the existing format (Appendix 3.1). A confirmation of improvement in the perceived value through an increased repeat purchase intention is a good indicator for higher market success.

6.4 Applications to innovations of FCFs and related foods

While the model is not complete for universal industrial application constituent parts of the model can be trialled for commercial product development to increase perceived value. To apply Phase 1 of the model (Fig. 3.1), consumer assessment of existing product lines is required in order to generate innovation ideas that can be tested for their ability to increase perceived value. Consumer surveys using BWS may be utilised. The constructs of options for participants to choose from can be derived from literature or internal experience and they can be confirmed through test runs of the surveys. The use of consumer surveys with BWS, like the study of (Lockshin et al., 2015), is recommended rather than the Likert scale. BWS relates more to the actual behaviour rather than the stated importance of factors influencing purchase or non-purchase as in the Likert scale. For in-depth interviews, the laddering technique may be utilised to understand the value perceptions for existing and future products. Moreover, product-related cues of perceived value may be identified using this elicitation technique and linked to product components that can be transformed during innovation cycles. Laddering is typically used to encourage self-analysis of behaviour and motivations. The structured questioning is commonly performed with individuals (Van Kleef et al., 2005). The results of Phase 1 implementation using mini groups, however, showed that it can also be applied to mini focus group interviews. With this format, more information can be derived in one session compared to the individual interview format to increase speed and efficiency of the process.

To apply Phase 2, it is recommended to undertake small-scale consumer testing with volatile analysis where available. The consumer test allows for determining consumer acceptability of product quality while volatile analysis enables objective measurement of the quality changes. The use of in-house panels is recommended for efficient routine screening (Hampson et al., 2000) such as testing of developed or improved products in each IC. When asked to evaluate the products, based on liking or acceptability, the in-house panel can mimic how retail consumers would assess the FCFs.

For objective measurements, several instrumental analyses can be used. However, volatile analysis is recommended because flavour changes faster than appearance and is critical to repeat purchase (Beaulieu and Baldwin, 2002). The combination of consumer testing and volatile analysis to assess the quality of fruit and fruit-related products is also common in literature. This combined testing and analysis were used in the studies on mango (Sung et al., 2019), FC pear (Taiti et al., 2017), and FC pineapple (Schulbach et al., 2007). However, these studies have been limited to only justify the acceptability of products, based on specific volatile compounds. In this study, the combination of the consumer test and volatile analysis, and the linkage of results provided a database of marker volatile compounds or OACs. These marker volatile compounds may be used as indicators of positive or negative changes in the product quality as affected by technical innovations. In addition, the use of PTR-MS for rapid volatile change monitoring is recommended, if available, once OACs are identified. The PTR-MS analysis for the marker compounds gives quick and reliable results that will allow rapid testing of postharvest processing and packaging techniques that are suitable for the fruit being tested. Most FC companies, however, are lacking of sophisticated analytical instruments such as PTR-MS because they are expensive and required specialist operators. Instead, collaboration with research laboratories or analytical services is a practical option.

The simulations of purchase and consumption for developed FCFs in Phase 3 of the model are recommended in order to test the perceived value improvement of the FCFs in the market. They must be constructed to be as close as possible to real market situations. Combined DCE and informed consumer testing was a useful technique to run the purchase and consumption simulations. The simulation tests allowed for the testing the effects of both extrinsic and intrinsic product cues on preference, liking and purchase intentions. In the recent reviews of Symmank (2019) and Asioli et al. (2017), a number of studies have used consumer and sensory science research methods to test the combined product extrinsic and intrinsic cues. Most of these studies, however, looked at the effects of combined extrinsic and intrinsic cues on either consumer preference or product acceptability. Previous to this work, there was only the study of Mueller et al. (2010) that performed purchase and consumption simulations. They also used DCE and informed consumer testing for determining the effects of extrinsic and intrinsic cues of Australian wines to consumer preference, liking and purchase intention. While the study of Mueller et al. (2010) have shown the applicability of conducting purchase and consumption simulations for long-life food and beverage products, such as wine, this current research has shown its applicability for short-life products such as FCFs.

6.5 Contributions to food innovation

This research has provided an extension of the Quality Guidance model (QGM) of Steenkamp and van Trijp (1996) in order to deliver improved food products. QGM has been widely used for food innovation, particularly in improving intrinsic product cues. The study of van den Heuvel et al. (2007) extended the QGM to include credence cues in improving food products. A further extension was made in this PVI model by including most important intrinsic and extrinsic product cues that are associated to perceived value of the current and potential end-users. Similar to the previous models, the product cues were also linked to the physical product components in order to produce the improved formats. The purchase and consumption simulations of actual products used in this research were lacking from the previous models of Steenkamp and van Trijp (1996) and van den Heuvel et al. (2007). The outcomes of the implementation of the PVI model have provided evidence of wider applicability to food innovation.

The research has also showcased the OACs as a research tool for indication of improved product prototypes. OACs have been identified in order to explain consumer preference and acceptability of the product in focus. The technical ICs in Phase 2 of the PVI model used a combined consumer sensory test and volatile data analysis to determine prototypes with improved perceived sensory freshness. The research tool that was used in the three ICs of the PVI model implementation in this research could be utilised to test innovations of other food products. The volatile compound markers may be associated to the fresh quality or best state of the product; or to its staleness and microbial degradation that relates to limiting storage time.

Additionally, the research has exhibited the practical applications of combined purchase and consumption simulations in testing the improvement of convenience products. The combined simulation techniques of DCE and informed consumer sensory test has been previously carried out in food products such as wine (Mueller et al., 2010), dry-cured ham (Hersleth et al., 2011), smoked salmon (Almli and Hersleth, 2013), boar-tainted frankfurter sausages (Kallas et al., 2016), tinned Chianina meat (Torquati et al., 2018), and pork product (Kallas et al., 2019). These food products, however, have shelf-lives longer than a month and thus, the purchase and consumption simulations were conducted on separate days. Moreover, the preparation, handling and storage of samples of these products for consumer sensory testing were less tedious. The methods of DCE and informed consumer sensory testing experiments used in this research could therefore serve as a guide in carrying out similar experiments for other convenient, ready-to-eat and highly perishable products.

6.6 Limitations of the model and future research recommendations

This thesis on PVI model implementation does not claim completeness, but intends to provide an evidence of feasibility for industry application and identify limitations for future work. Like any other research, this PVI model research has its own limitations from which implications for further research can be developed. One of the limitations identified is its lack of innovation efficiency measurement. Innovation projects, such as the implementation of the PVI model, must be evaluated based on effectiveness and efficiency (Olson et al., 1995). Effectiveness refers to economic success and quality of the product while efficiency covers the timeliness and amount of resources utilised in the project (Brettel et al., 2011). Currently, the PVI model was only tested for its ability to produce consumer-effective FCFs. The cost and time of implementing each of the phase was not taken into account, as it was beyond the scope of the research. Monitoring cost and time in the PVI model for future implementation is therefore recommended in order to measure and improve the innovation efficiency of the model (Fig. 6.2).

The framework and measurements of the technical innovation efficiency in the study of Cruz-Cázares et al. (2013) may be used for future developments of the PVI model. In their study, inputs from the innovation stage, that were identified as R&D capital stock, and highly-skilled staff were utilised to produce outputs such as new products and patents. The outputs from the innovation stage were then utilised as the basis for determining the performance of the company, which was measured in terms of return on assets (ROA). The ROA in their study was measured based on the number of product innovations, age and size of the company patents and technological intensity levels (Cruz-Cázares et al., 2013). The methods of measuring the technical innovation efficiency and performance of the company in their study may be used as a guide to determine the technical innovation efficiency of the PVI model.

Another recommendation for future work is the extension of the PVI model to include the product life cycle (PLC) (Fig. 6.2). The model development was limited up to market testing only, due to resource constraints. By including PLC for future research, data from the end-users can be utilised to formulate market strategy in order to maximise demand before an alternative product is introduced (Fuller, 2016). The recommendations in the study of Horvat et al. (2019) on consumer involvement in the PLC can be used as a guide to develop and test the extension of the PVI model. PLC typically consists of 4 phases: introduction, growth, maturity, and decline where the end-users are also actively involved (Fig. 6.2).

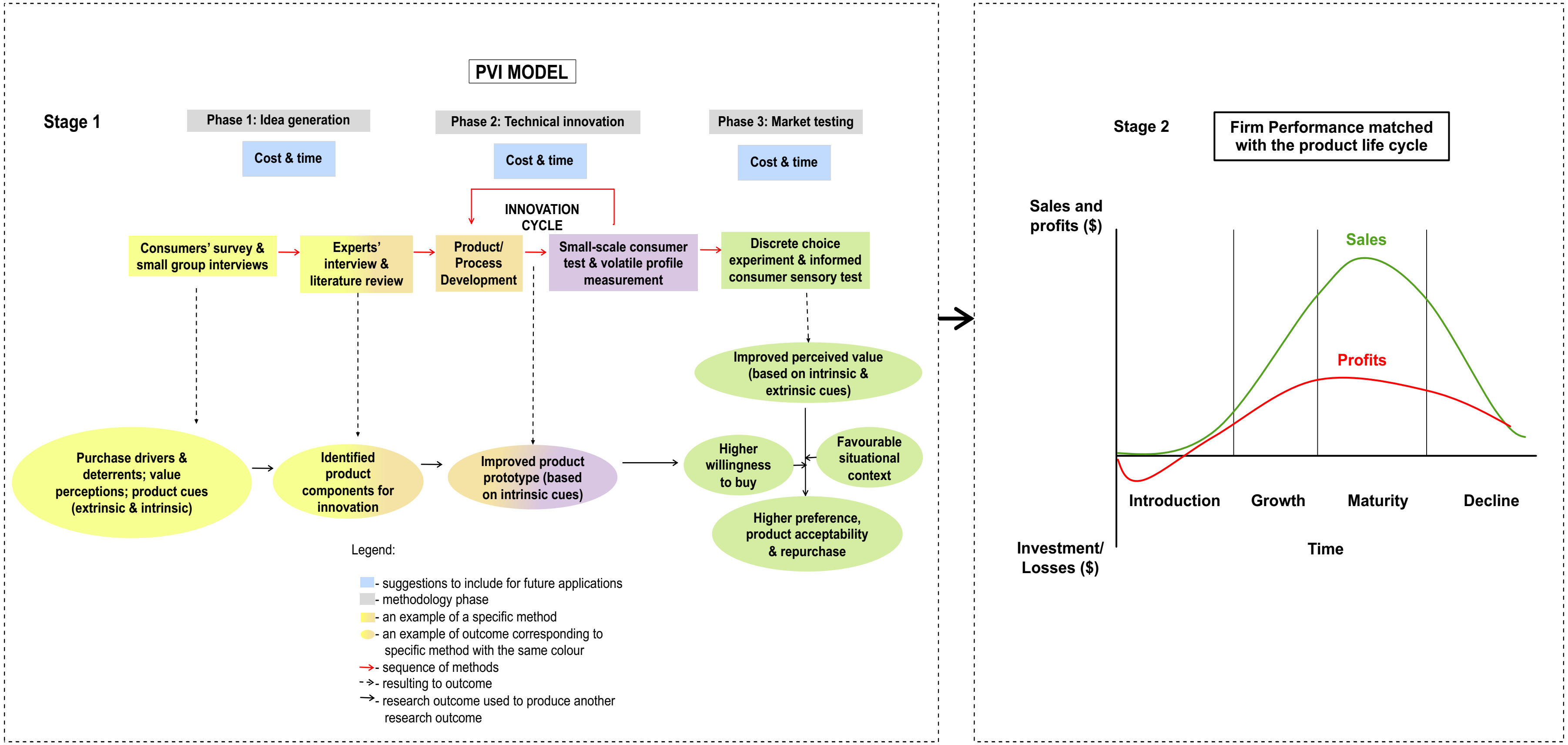

Fig. 6.2. Suggested improvements for the PVI Model and future research recommendations.

Note: Product Life Cycle model was derived from Grunert and van Trijp (2014a) and the model of innovation efficiency measurement was adapted from Cruz-Cázares et al. (2013).

The PLC can also be used to measure the effectiveness and efficiency of the model. The growth and maturity stages of the product developed from the PVI model would indicate how effective the model is. Additionally, the profit and sales at these stages can be used to evaluate ROA of the company. The number of product innovations and number of patents in the study Cruz-Cázares et al. (2013) may be changed into the profit and sales incurred from selling that the products developed from the PVI model. This modification in the measurement of ROA may be a better representation of the effect of innovation to the performance of the company and therefore, measure the innovation efficiency more accurately.

The limitations of PVI model in each phase were also identified, and therefore future research recommendations are summarised as follows. In Phase 1, the implementation was only limited to the classification of respondents based on attitude and behaviour towards FCFs (current and potential product users). An extension to include target market belonging to different demographic groups would cover wider value perceptions which may result in market expansion, and thus, is recommended.

In Phase 2, the selection of postharvest techniques has not considered the perceptions of respondents towards specific technology applied. Negative perceptions towards the technology applied, even when the resulting sensory quality of the product is acceptable, may impair product acceptability. The perceptions of the target market towards technology to be used is therefore recommended for future applications of the model in order to ensure product acceptability. Moreover, the application of technologies and experiments in the ICs has only led to product performance leadership. FCF companies can exert effort to improve the perceived value of FCF by raising the performance leadership or the cost leadership of FCFs. Performance leadership normally entails high cost while cost reduction lowers product quality performance (Amini et al., 2014). Increasing the perceived value of FCFs by improving its performance with the least amount of cost is ideal and rare. On one hand, improving product performance with a comparable production cost from existing products, is practical in raising the perceived value of FCFs. Cost of technology application should therefore be a consideration in the selection of postharvest techniques in the future. The selection of technology applications is product specific. In this application the implementation of PVI model was limited to the product and technologies available to the industry partner. For future applications, the model can also be applied to other FCFs.

In Phase 3, the DCE experiments was also limited to a number of extrinsic product cues. Although the price information may have been taken into account, it was only based on the production cost (i.e. raw materials and labour) and the desired margin. Future research can extend the DCE by varying price in order to determine the actual price point sensitivity of the current and potential end-users of the FCFs. Additionally, a final binding choice task can be performed after purchase and consumption simulations, and repeat purchase intention tasks. The binding choice task requires participants to pay the corresponding price of their choice from a given amount as part of the experiment and allows for a more realistic purchase scenario (Ballco and Gracia, 2020).

6.7 Conclusions

The PVI model was effective in delivering commercially-produced FCFs with improved perceived value. The outcomes of development and testing of the PVI model were applied by the partner FC company. The increase in the sales volume of the FCW formats, developed from the PVI model, validated its effectiveness in improving the perceived value of end-users for the product. This economic outcome has also proven the practicality of integrating market and technical innovations in the PVI model to the FC industry.

The PVI model could also be applied to any existing food product. Processing technologies to be implemented, however, should be carefully selected. The choice is product-dependent, limited by company resources and are subject to consumer perceived value and acceptability. The model also currently lacks the consideration of the cost and time requirements for the actual innovation, production and market testing. Consequently, future developments would need to incorporate these efficiency factors in order to fully evaluate the success of the PVI model. Nonetheless, the application of the model is useful to develop leading-edge FCFs and related food products in comparison to competitor offerings.

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Appendices

Appendix 3.1. Current formats of FCF and FCW.

Existing mixed FCF format

Current FCW format

Note: Photos used with permission from PFA Pty L

Appendix 3.2. Consumer survey for current end-users of FCFs.

ID #: _______ SURVEY ABOUT FRESH-CUT FRUITS Date: _______

This questionnaire is about the purchase of fresh-cut fruits. Please answer parts 1 and 2. Please note there are no right or wrong answers. It is your honest thoughts we wish to know. This survey will only take 5-7 minutes to complete. Thank you.

Part 1.

1. a. PLEASE LOOK AT EACH SET OF FACTORS ONE AT A TIME.
b. TICK ONE MOST IMPORTANT FACTOR in your choice to buy fresh-cut fruits and the ONE THAT IS LEAST.

MOST		LEAST
☐	Fruits look fresh	☐
☐	Juice at the bottom of the package	☐
☐	Packaging size	☐
☐	Price	☐

MOST		LEAST
☐	Product's location in store	☐
☐	Promotional display in store	☐
☐	Contains my favourite fresh-cut fruits	☐
☐	Packaging size	☐

MOST		LEAST
☐	Juice at the bottom of the package	☐
☐	Shape of fruit pieces	☐
☐	Packaging shape	☐
☐	Contains my favourite fresh-cut fruits	☐

MOST		LEAST
☐	Promotional display in store	☐
☐	Price	☐
☐	*Remains fresh throughout the day	☐
☐	Packaging shape	☐

MOST		LEAST
☐	Shape of fruit pieces	☐
☐	Packaging size	☐
☐	Information on the label	☐
☐	*Remains fresh throughout the day	☐

MOST		LEAST
☐	Price	☐
☐	Contains my favourite fresh-cut fruits	☐
☐	Use-by date	☐
☐	Information on the label	☐

MOST		LEAST
☐	Packaging size	☐
☐	Packaging shape	☐
☐	The place I buy is close to where I am	☐
☐	Use-by date	☐

MOST		LEAST
☐	Contains my favourite fresh-cut fruits	☐
☐	*Remains fresh throughout the day	☐
☐	Fruits look fresh	☐
☐	The place I buy is close to where I am	☐

MOST		LEAST
☐	Packaging shape	☐
☐	Information on the label	☐
☐	Product's location in store	☐
☐	Fruits look fresh	☐

MOST		LEAST
☐	*Remains fresh throughout the day	☐
☐	Use-by date	☐
☐	Juice at the bottom of the package	☐
☐	Product's location in store	☐

MOST		LEAST
☐	Information on the label	☐
☐	The place I buy is close to where I am	☐
☐	Promotional display in store	☐
☐	Juice at the bottom of the package	☐

MOST		LEAST
☐	Use-by date	☐
☐	Fruits look fresh	☐
☐	Shape of fruit pieces	☐
☐	Promotional display in store	☐

MOST		LEAST
☐	The place I buy is close to where I am	☐
☐	Product's location in store	☐
☐	Price	☐
☐	Shape of fruit pieces	☐

Please write down other MOST important factors (not listed above) in your choice to buy fresh-cut fruits:

____

____

____

** This means that the product doesn't go off easily even when consumed later in the day.*

Page 1 of 2

2. How familiar are you with fresh-cut fruits?

☐ Not at all ☐ Slightly ☐ Moderately ☐ Quite ☐ Very

3. How often do you buy fresh-cut fruits?

☐ everyday ☐ 4-6 times a week ☐ 1-3 times a week ☐ 1-3 times a fortnight ☐ 1-3 times a month

4. When you buy fresh-cut fruit, do you eat it immediately in one go? ☐ yes ☐ no

If no, how long does it take for you to consume it all? _______ hours or __________ days

5. How important are the following in your repeat purchase?

Attributes	Not at all	Slightly	Moderately	Quite	Very
easy to open packaging	☐	☐	☐	☐	☐
spoon/ fork included	☐	☐	☐	☐	☐
smell of fruits upon opening the package	☐	☐	☐	☐	☐
taste freshness	☐	☐	☐	☐	☐
fruity flavour	☐	☐	☐	☐	☐
crunchiness	☐	☐	☐	☐	☐
others, please specify ______________________________	☐	☐	☐	☐	☐

6. Any suggestions that would make these products more appealing to you?

____

Part 2. Please also answer the following questions by placing a tick in the appropriate box or fill in the space.

1. Gender: ☐ male ☐ female
2. Age: ______
3. How many people are living with you? ________
4. Do you also buy fresh-cut fruit for them? ☐ YES ☐ NO
5. Do you have school-aged children who are living with you who also eat fresh-cut fruits? ☐ YES ☐ NO
6. Weekly food budget: ______
7. Do you work/study from home? Does this impact your spending time to prepare food? ☐ YES ☐ No

   If YES, are you ☐ FULL-TIME ☐ PART-TIME

8. Where do you live? ☐ CBD ☐ intercity ☐ suburban ☐ rural ☐ others, please specify _________
9. What is your cultural background?

☐ Australian	☐ Chinese- Australians	☐ Indigenous Australian	☐ Lebanese-Australian
☐ African	☐ European	☐ Irish-Australian	☐ Vietnamese-Australian
☐ American	☐ Filipino-Australian	☐ Italian-Australian	☐ others, please specify
☐ Asian	☐ Greek-Australian	☐ Latin-American	____________________

10. If you are willing to participate in the next part of this project (consumer product tests and focus group discussions), please provide your contact details below. Thank you.

Name: ____________________________

Email address: ______________________

Mobile number: ______________________

You are finished. Thank you for your participation. We sincerely appreciate your feedback.

Page 2 of 2

Appendix 3.3. Consumer survey for non-users of FCFs.

ID #: _______ **SURVEY ABOUT NOT BUYING FRESH-CUT FRUIT** **Date: _______**

This questionnaire is about reasons for not buying fresh-cut fruits. Please answer parts 1 and 2. Please note there are no right or wrong answers. It is your honest thoughts we wish to know. This survey will only take 5-7 minutes to complete. Thank you.

Part 1.
1. a. PLEASE LOOK AT EACH SET OF REASONS ONE AT A TIME.
b. TICK ONE MOST IMPORTANT REASON why you don't buy fresh-cut fruits and the ONE THAT IS LEAST.

MOST		LEAST
☐	Doesn't look fresh	☐
☐	Shorter shelf-life	☐
☐	Doesn't contain my favourite fruits	☐
☐	Don't trust the quality	☐

MOST		LEAST
☐	Shorter shelf-life	☐
☐	Range not appealing	☐
☐	Unnecessary packaging	☐
☐	Just haven't tried it	☐

MOST		LEAST
☐	Range not appealing	☐
☐	Doesn't contain my favourite fruits	☐
☐	Portion size not right for me	☐
☐	Not readily available	☐

MOST		LEAST
☐	Doesn't contain my favourite fruits	☐
☐	Unnecessary packaging	☐
☐	Too expensive	☐
☐	Store where to buy is far from my location	☐

MOST		LEAST
☐	Unnecessary packaging	☐
☐	Portion size not right for me	☐
☐	Not my habit	☐
☐	Doesn't look fresh	☐

MOST		LEAST
☐	Portion size not right for me	☐
☐	Too expensive	☐
☐	Prefers to cut fruit myself	☐
☐	Shorter shelf-life	☐

MOST		LEAST
☐	Too expensive	☐
☐	Not my habit	☐
☐	Don't trust the quality	☐
☐	Range not appealing	☐

MOST		LEAST
☐	Not my habit	☐
☐	Prefers to cut fruit myself	☐
☐	Just haven't tried it	☐
☐	Doesn't contain my favourite fruits	☐

MOST		LEAST
☐	Prefers to cut fruit myself	☐
☐	Don't trust the quality	☐
☐	Not readily available	☐
☐	Unnecessary packaging	☐

MOST		LEAST
☐	Don't trust the quality	☐
☐	Just haven't tried it	☐
☐	Store where to buy is far from my location	☐
☐	Portion size not right for me	☐

MOST		LEAST
☐	Just haven't tried it	☐
☐	Not readily available	☐
☐	Doesn't look fresh	☐
☐	Too expensive	☐

MOST		LEAST
☐	Not readily available	☐
☐	Store where to buy is far from my location	☐
☐	Shorter shelf-life	☐
☐	Not my habit	☐

MOST		LEAST
☐	Store where to buy is far from my location	☐
☐	Doesn't look fresh	☐
☐	Range not appealing	☐
☐	Prefers to cut fruit myself	☐

Please write down other MOST important reasons (not listed above) why you DO NOT buy fresh-cut fruits:

____

____

____

2. How familiar are you with fresh-cut fruits?

☐ Not at all ☐Slightly ☐Moderately ☐Quite ☐Very

3. Is there any chance you'd be buying them in the future? ☐ Yes ☐Maybe ☐No

If YES or MAYBE, In what instance will you buy these products? Please cite scenarios.

____

____

4. Any suggestions that would make these products appealing to you?

____

____

Part 2. Please also answer the following questions by placing a tick in the appropriate box or fill in the space.

1. Gender: ☐ male ☐female
2. Age: ______
3. How many people are living with you? ________
4. Do you also buy fruit for them? ☐ YES ☐ NO
5. Do you have school-aged children who are living with you who also eat fruits? ☐ YES ☐ NO
6. Weekly food budget: ______
7. Do you work/study from home? Does this impact your spending time to prepare food? ☐YES ☐No

   If YES, are you ☐ FULL-TIME ☐ PART-TIME

8. Where do you live? ☐ CBD ☐ intercity ☐ suburban ☐ rural ☐ others, please specify _________

9. What is your cultural background?

☐ Australian	☐ Chinese- Australians	☐ Indigenous Australian	☐ Lebanese-Australian
☐ African	☐ European	☐ Irish-Australian	☐ Vietnamese-Australian
☐ American	☐ Filipino-Australian	☐ Italian-Australian	☐ others, please specify
☐ Asian	☐ Greek-Australian	☐ Latin-American	________________

10. If you are willing to participate in the next part of this project (consumer product tests and focus group discussions), please provide your contact details below. Thank you.

    Name: __________________________

    Email address: ______________________

    Mobile number: ______________________

You are finished. Thank you for your participation. We sincerely appreciate your feedback.

Appendix 3.4. Experimental set-up for consumer survey in supermarkets.

Note: Photo reproduction with signed consent from the participants.

Intercept-administered survey conducted at Woolworths Central Supermarket

Intercept-administered survey conducted at Woolworths Town Hall

Appendix 3.5. Experimental set-up for mini focus group and individual in-depth interviews.

Note: Photo reproduction with signed consent from the participants.

(a), (b) and (c) – mini focus group interviews; (d) individual in-depth interview

Appendix 4.1. Pathogen and coliform results of FCW samples.

Samples tested	***Salmonella spp***	***L. monocytogenes***	***E.coli***	***Faecal coliforms***	***Coagulase Positive Staph.***
Limits	ND in 25g	ND in 25g	<3.0 MPN/g	<3.0 MPN/g	<100 CFU/g
AP [c]	ND	ND	<3.0	<3.0	<100
MP	ND	ND	<3.0	<3.0	<100
Ap	ND	ND	<3.0	<3.0	<100
Mp	ND	ND	<3.0	<3.0	<100
MN	ND	ND	<3.0	<3.0	<100
AN	ND	ND	<3.0	<3.0	<100
AnT	ND	ND	<3.0	<3.0	<100
ANVL	ND	ND	<3.0	<3.0	<100
AnTVL	ND	ND	<3.0	<3.0	<100

Conditions: All samples were stored at 3 °C for 1 to 8 d; AP = air perforated with larger perforations; MP = MAP perforated with bigger perforations; Ap = air perforated with smaller perforations; Mp = MAP perforated with smaller perforations; MN = MAP non-perforated; AN = air non-perforated; AnT = air non-perforated without post-cut sanitation step; ANVL = air non-perforated with post-cut sanitation step and with mint leaves and AnTVL = air non-perforated without post-cut sanitation step and with mint leaves; Lidding film with larger perforations have 6 × 150 µm holes while those with smaller perforations have 6 × 75 µm holes.

Appendix 4.2. Volatile composition of fresh and stored watermelon samples.

Volatile compounds	RI	Lit. ref.	Treatments								Std. error	P-val
			Fresh	AnT	AN	Ap	Mp	AP	MP	MN		
acetaldehyde	703	4, 5, 6, 8	529^{a}	456^{a}	190^{d}	301^{bc}	370^{b}	303^{bc}	274^{c}	304^{bc}	0.267	< 0.0001
2-butanone*	906	-	9^{f}	38^{e}	195^{a}	146^{b}	196^{a}	52de	59^{d}	116^{c}	0.108	< 0.0001
3-methylbutanal*	916	3, 11	24^{a}	2^{d}	6^{cd}	16^{b}	10^{bc}	2^{d}	3^{d}	5^{cd}	0.272	< 0.0001
ethanol*	947	5, 8, 9, 11	34^{f}	276^{cd}	115^{ef}	116^{ef}	384^{ab}	192de	301^{bc}	410^{a}	0.219	< 0.0001
1-penten-3-one*	1029	1, 6	55^{a}	1^{b}	4^{b}	0^{b}	0^{b}	0^{b}	0^{b}	54^{a}	0.126	< 0.0001
hexanal*	1096	1, 2, 3, 4, 5, 6, 8, 9, 10, 11	452^{a}	27^{b}	71^{b}	41^{b}	59^{b}	6^{b}	3^{b}	406^{a}	0.151	< 0.0001
(D) -limonene*	1198	3, 8	0^{d}	13^{cd}	69^{b}	13^{cd}	77^{b}	18^{c}	17^{c}	233^{a}	0.069	< 0.0001
(E) -2-hexenal*	1231	1, 3, 6, 9, 10, 11	13^{b}	2^{c}	5^{bc}	2^{c}	6^{bc}	0^{c}	0^{c}	34^{a}	0.266	< 0.0001
2-pentylfuran*	1232	1, 3, 6, 9, 10,	159^{bc}	61^{cd}	254^{b}	52^{cd}	33^{d}	152^{bcd}	121^{cd}	422^{a}	0.302	< 0.0001
3-octanone*	1268	6	18^{a}	11^{bc}	14^{ab}	6^{d}	9^{cd}	8^{cd}	6^{d}	17^{a}	0.279	< 0.0001
octanal*	1298	1, 2, 3, 6, 9, 10	30^{a}	2^{b}	5^{b}	1^{b}	1^{b}	1^{b}	0^{b}	24^{a}	0.204	< 0.0001
1-octen-3-one*	1313	1, 3, 6, 10	10^{a}	1^{b}	1^{b}	1^{b}	1^{b}	1^{b}	1^{b}	12^{a}	0.225	< 0.0001
(E) -2-heptenal*	1335	1, 2, 5, 6, 9, 10, 11	22^{a}	4^{bc}	7^{b}	0^{c}	0^{c}	0^{c}	0^{c}	23^{a}	0.218	< 0.0001
(Z) -2-penten-1-ol*	1338	1, 5, 10	23^{b}	5^{c}	19^{b}	9^{c}	8^{c}	6^{c}	5^{c}	36^{a}	0.255	< 0.0001
6-methyl-5-hepten-2-one	1348	1, 2, 3, 4, 5, 6, 7, 9, 10	147^{ab}	156^{ab}	68^{c}	118^{b}	168^{a}	67^{c}	61^{c}	154^{ab}	0.254	0.0000
1-hexanol*	1367	1, 2, 3, 4, 6, 9, 10	139^{bcd}	110^{cde}	190^{a}	140^{bcd}	175^{ab}	103de	94^{e}	148^{abc}	0.375	0.0020
(Z) -3-hexen-1-ol*	1391	1, 3, 6, 8, 9, 10	43^{bc}	21de	26^{cde}	63^{a}	53^{ab}	31^{cde}	36^{bcd}	17^{e}	0.356	0.0010
dimethyl trisulfide*	1393	Not reported	0^{c}	1^{c}	4^{b}	1^{c}	1^{c}	0^{c}	0^{c}	16^{a}	0.194	< 0.0001
nonanal*	1397	1, 2, 3, 4, 5, 6, 9, 10, 11	629^{b}	30de	111^{c}	24de	49^{d}	24de	4^{e}	716^{a}	0.049	< 0.0001
(E) -2-octenal*	1441	1, 2, 3, 6, 9, 10, 11	54^{a}	6^{b}	6^{b}	3^{b}	6^{b}	6^{b}	4^{b}	58^{a}	0.117	< 0.0001
1-octen-3-ol*	1456	1, 10	136^{a}	33^{bc}	53^{b}	18^{c}	25^{c}	11^{c}	11^{c}	126^{a}	0.172	< 0.0001
(Z) -6-nonenal*	1460	1, 2, 3, 5, 6, 9, 11	260^{a}	9^{b}	28^{b}	11^{b}	14^{b}	8^{b}	2^{b}	296^{a}	0.179	< 0.0001
acetic acid*	1463	8	65^{a}	4^{c}	33^{b}	11^{bc}	12^{bc}	11^{bc}	23^{bc}	33^{b}	0.39	0.0020
1-heptanol*	1466	4, 6	12^{bc}	12^{cd}	15^{b}	5^{f}	8^{ef}	10^{cde}	8^{def}	26^{a}	0.168	< 0.0001
6-methyl-5-hepten-2-ol	1472	3, 5	2^{f}	78^{a}	26^{d}	43^{c}	55^{b}	13^{e}	11^{ef}	14^{e}	0.176	< 0.0001
(E,E) -2,4-heptadienal*	1475	1, 2, 3, 6, 9, 10	0^{d}	7^{c}	14^{b}	0^{d}	0^{d}	0^{d}	0^{d}	63^{a}	0.046	< 0.0001
decanal*	1506	2, 3	10^{ab}	1^{b}	22^{a}	1^{b}	1^{b}	2^{b}	traces^{b}	17^{a}	0.427	0.0110
(E) -2-nonenal*	1547	1, 2, 3, 4, 5, 6, 8, 9, 11	1466^{a}	87^{b}	113^{b}	148^{b}	196^{b}	71^{b}	11^{b}	1354^{a}	0.194	< 0.0001
(β) -linalool*	1554	Not reported	0^{d}	3^{c}	7^{b}	1^{cd}	2^{c}	6^{b}	8^{b}	28^{a}	0.086	< 0.0001
(E,Z)- 2,6-nonadienal*	1598	1, 2, 3, 4, 5, 6, 8, 9, 10, 11	1382^{b}	76^{c}	211^{c}	198^{c}	256^{c}	103^{c}	17^{c}	2385^{a}	0.14	< 0.0001
(β) -cyclocitral	1640	2, 3, 5, 7	2^{a}	2^{a}	0^{b}	1^{b}	1^{b}	1^{b}	traces^{b}	3^{a}	0.316	0.0000
acetophenone*	1667	10	0^{b}	1^{b}	17^{b}	0^{b}	0^{b}	0^{b}	0^{b}	80^{a}	0.381	0.0030
1-nonanol*	1672	1, 2, 3, 4, 5, 6, 8, 9, 10, 11	1249^{a}	371^{b}	145^{c}	139^{c}	200^{bc}	232^{bc}	99^{c}	177^{bc}	0.179	< 0.0001
(Z)- citral*	1697	6	2778^{a}	844^{b}	209^{c}	623^{bc}	645^{bc}	456^{bc}	534^{bc}	424^{bc}	0.216	< 0.0001
(Z) -3-nonen-1-ol	1699	1, 2, 3, 4, 5, 8, 9, 10, 11	3700^{a}	1102^{b}	267^{c}	812^{bc}	844^{bc}	597^{bc}	701^{bc}	558^{bc}	0.215	< 0.0001
cyclogeraniolene	1715	Not reported	0^{e}	14^{b}	1de	4^{cd}	12^{b}	6^{c}	0^{e}	52^{a}	0.061	< 0.0001
(E)- 2-nonen-1-ol	1727	1, 9, 11	219^{a}	137^{b}	20^{c}	29^{c}	205^{a}	27^{c}	19^{c}	105^{b}	0.174	< 0.0001
(Z)- 6-nonen-1-ol*	1730	1, 2, 3, 4, 5, 6, 9, 10, 11	507^{a}	209^{c}	290^{bc}	234^{c}	207^{c}	387^{ab}	234^{c}	209^{c}	0.394	0.0030
(R)- carvone	1758	Not reported	0^{c}	5^{bc}	0^{c}	0^{c}	0^{c}	19^{b}	10^{bc}	126^{a}	0.119	< 0.0001
(Z,Z)- 3,6-nonadien-1-ol	1765	4, 5, 6, 8, 9, 10, 11, 12	2908^{a}	770^{bc}	321^{c}	702^{bc}	741^{bc}	684^{bc}	892^{b}	470^{bc}	0.21	< 0.0001
(E,Z)- 2,6-nonadien-1-ol	1777	1, 2, 9, 10, 11	65^{b}	50^{bc}	41^{c}	37^{c}	97^{a}	39^{c}	5^{d}	58^{bc}	0.276	< 0.0001

* Confirmed by reference standard; RI, retention index; Lit. Ref. – previously reported in: 1 = Liu et al. (2018); 2 = Fredes et al. (2016); 3 = Dima et al. (2014); 4 = Xisto et al. (2012); 5 = Saftner et al. (2007); 6 = Beaulieu and Lea (2006); 7 = Lewinsohn et al. (2005); 8 = Pino et al. (2003); 9 = Kim et al. (1999); 10 = Yajima et al. (1985); 11 = Kemp (1975); 12 = Kemp et al. (1974); Note: different letter superscripts are significantly different at $p < 0.05$.

Appendix 4.3. Volatile composition of FCW samples with and without mint leaves.

Volatile compounds	LRI	Fresh (0 d)	AN	ANVL	Std. error	*p*-val
acetaldehyde	704	529 [a]	343 [b]	248 [c]	28.425	0.0010
2-butanone	906	0.375	65 [b]	65 [b]	3.859	< 0.0001
3-methyl-1-butanal	917	24 [a]	7 [b]	7 [b]	1.943	0.0010
ethanol	947	33 [a]	199 [b]	190 [b]	15.756	0.0010
(α)-pinene	1026	0 [a]	0 [a]	125 [b]	1.058	< 0.0001
1-penten-3-one	1029	55 [a]	2 [b]	8 [b]	4.368	0.0000
hexanal	1096	452 [a]	63 [b]	80 [b]	33.375	0.0000
(β)-myrcene	1160	0 [a]	0 [a]	624 [b]	17.031	< 0.0001
(D)-limonene	1198	2 [a]	8 [a]	5051 [b]	177.084	< 0.0001
eucalyptol	1206	0 [a]	0 [a]	381 [b]	54.247	0.0040
(E)-2-hexenal	1231	13 [a]	4 [a]	54 [b]	6.357	0.0030
2-pentylfuran	1233	159 [a]	126 [a]	168 [a]	37.098	0.7110
3-octanone	1268	18 [a]	14 [a]	16 [a]	1.616	0.3390
3-methyl-1-butanol	1270	25 [a]	8 [b]	6 [b]	1.813	0.0010
octanal	1298	30 [a]	4 [b]	8 [b]	3.599	0.0040
1-octen-3-one	1313	10 [a]	1 [b]	1 [b]	0.56	< 0.0001
(Z)-2-heptenal	1335	22 [a]	7 [b]	9 [b]	3.356	0.0450
6-methyl-5-hepten-2-one	1348	147 [a]	155 [a]	129 [a]	20.135	0.6630
1-hexanol	1367	139 [a]	113 [a]	59 [b]	14.073	0.0190
dimethyl trisulfide	1393	0.00 [a]	0.19 [a]	0.00 [a]	0.059	0.1030
nonanal	1397	629 [a]	96 [c]	279 [b]	19.953	< 0.0001
(Z)-3-hexen-1-ol	1391	82 [a]	9 [a]	15 [a]	24.783	0.1480
(E)-2-octenal	1441	54 [a]	12 [b]	24 [b]	4.391	0.0010
1-octen-3-ol	1456	136 [a]	37 [b]	72 [b]	14.985	0.0090
(E)-6-nonenal	1460	260 [a]	18 [b]	68 [b]	34.179	0.0060
acetic acid	1463	65 [a]	10 [b]	22 [b]	12.096	0.0400
1-heptanol	1466	12 [a]	12 [ab]	7 [b]	1.525	0.0980
6-methyl-5-hepten-2-ol	1472	2 [a]	64 [b]	61 [b]	5.902	0.0010
(E,E)-2,4-heptadienal	1475	0 [a]	3 [b]	7 [c]	0.597	0.0000
decanal	1506	10 [a]	2 [b]	5 [c]	0.594	0.0000
(E)-2-nonenal	1547	1466 [a]	293 [b]	775 [b]	188.109	0.0130
(β)-linalool	1554	3 [a]	5 [a]	39 [b]	6.263	0.0110
(E,Z)-2,6-nonadienal	1598	1382 [a]	238 [b]	1028 [a]	189.412	0.0140
(E)-dihydrocarvone	1607	0 [a]	0 [a]	22 [b]	4.563	0.0220
(β)-cyclocitral	1640	2 [a]	2 [a]	3 [a]	0.203	0.6620
acetophenone	1667	0 [a]	1 [b]	2 [b]	0.203	0.0020
1-nonanol	1672	1249 [a]	289 [b]	132 [b]	109.53	0.0010
(Z)-citral	1697	2778 [a]	723 [b]	600 [b]	289.849	0.0030
(Z)-3-nonen-1-ol	1699	3700 [a]	947 [b]	783 [b]	382.155	0.0030
(E,E)-2,4-nonadienal	1709	64 [a]	33 [a]	58 [a]	11.318	0.1940
(E)-2-nonen-1-ol	1727	222 [a]	224 [a]	129 [b]	23.584	0.0480
(Z)-6-nonen-1-ol	1730	507 [a]	146 [b]	111 [b]	57.683	0.0050
(S) or (R)-carvone	1758	0 [a]	4 [a]	5254 [b]	553.495	0.0010
(E,Z)-3,6-nonadien-1-ol	1765	2932 [a]	587 [b]	466 [b]	287.645	0.0010
(E,Z)-2,6-nonadien-1-ol	1777	9 [a]	2 [b]	3 [b]	0.752	0.0010
(E)-carveol	1846	0 [a]	0 [a]	7 [b]	1.105	0.0080

Conditions: All samples were stored at 3 °C for 8 d; ANVL = air non-perforated with mint leaves; AN= air non-perforated without mint leaves. Means (n= 3) with different superscripts are significantly different at $p < 0.05$.

Appendix 4.4. PTR-MS fragmentation patterns and relative abundance of reference standards.

Target m/z	Compound		Intensities of major mass ions *(m/z)* [a]															
41	3-methylbutanol	88	**41**(100)	37(88)	43(74)	71(35)	69(34)	39(24)	55(16)	83(16)	57(11)	32(10)	81(8)					
43	1-octen-3-ol	144	32(100)	69(43)	57(35)	30(30)	41(21)	**43**(14)	111(14)	67(12)	128(8)	81(8)	85(7)					
45	Acetaldehyde [b]	44	**45**(100)															
47	ethanol	46	37(100)	**47**(12)	32(10)	81(9)												
55	*(Z)*-3-hexen-1-ol	100	**55**(100)	83(84)	37(37)	84(6)	109(5)											
57	*(E)*-2-penten-1-ol	86	32(100)	30(30)	**57**(13)	69(7)	46(7)	41(6)										
61	acetic acid	60	**61**(100)															
67	decanal	156	32(100)	30(29)	**67**(13)	83(9)	55(9)	81(7)										
69	octanal	128	**69**(100)	41(52)	111(24)	55(14)	39(11)	57(10)	70(8)	129(5)	67(5)	37(5)	109(5)					
71	1-nonanol	144	37(100)	41(89)	57(86)	43(85)	**71**(33)	39(16)	85(13)	129(10)	59(6)							
73	2-butanone	72	**73**(100)	44(10)	55(6)													
81	1-octen-3-one	126	32(100)	30(27)	69(19)	57(17)	41(12)	43(8)	111(6)	**81**(6)	127(5)							
85	1-penten-3-one	84	**85**(100)	43(28)	86(10)	57(8)												
87	3-methylbutanal	86	32(100)	30(30)	58(27)	41(25)	43(19)	57(19)	44(18)	45(12)	**87**(8)	71(8)	43(7)	39(6)				
95	*(β)*-pinene	136	81(100)	137(30)	**95**(11)	93(1)	121(1)											
97	*(E,E)*-2,4-hexadienal	96	32(100)	81(56)	**97**(31)	30(28)	95(8)	46(6)										
99	*(E)*-2-hexenal	98	57(100)	81(34)	**99**(32)	37(7)	43(6)											
101	hexanal	100	55(100)	83(75)	84(6)	56(6)	39(5)	37(5)	**101**(4)									
109	*(E)*-2-octenal	126	**109**(100)	127(28)	67(19)	57(17)												
111	*(E,E)*-2,4-heptadienal	110	32(100)	81(79)	**111**(35)	30(27)	82(7)	109(6)	93(5)									
113	*(E)*-2-heptenal	112	**95**(100)	83(60)	57(55)	32(55)	**113**(43)	55(27)	112(25)	111(22)	30(20)	84(16)	67(14)					
121	*acetophenone*	120	**32(100)**	105(61)	30(29)	121(28)	**106(6)**											
123	*(E)-2-nonen-1-ol*	142	**69(100)**	41(56)	37(46)	83(38)	**55(36)**	57(32)	81(23)	123(17)	67(13)	39(12)	125(8)	141(7)				
127	*dimethyl trisulfide*	126	**126(100)**	79(45)	61(42)	93(27)	**32(23)**	128(18)	81(16)	80(16)	127(14)							
129	*3-octanone*	128	**129(100)**	130(14)	69(8)													
137	*(β)-myrcene*	136	**81(100)**	137(73)	95(41)	138(10)	**69(10)**	82(10)										
137	*(a)-pinene*	136	**81(100)**	137(60)	82(10)	138(8)	**95(8)**											
137	*(D)-limonene*	136	**81(100)**	137(43)	95(21)	82(11)	**138(6)**											
137	*(β)-linalool*	154	**81(100)**	137(54)	37(17)	69(10)	**95(9)**	138(7)	59(5)	41(5)								
139	*2-pentylfuran*	138	**139(100)**	140(16)														
59, 135	*citral*	152	**95(100)**	59(58)	30(42)	37(36)	**153(27)**	32(23)	135(23)	69(16)								
83, 143	*nonanal*	142	**69(100)**	41(72)	55(44)	83(39)	**57(29)**	37(26)	39(21)	143(10)	67(8)	70(7)	125(6)					
121, 139	*(E,E)-2,6-nonadienal*	138	**139(100)**	121(30)	37(27)	95(21)	**83(21)**	55(20)	57(14)	93(12)								
123, 141	*(E)-2-nonenal*	140	**123(100)**	81(92)	67(39)	141(38)	**57(30)**	124(12)	82(100)	37(6)	55(5)							
123, 141	*(Z)-6-nonenal*	140	**81(100)**	123(81)	67(60)	141(54)	**55(10)**	124(10)	82(9)	142(6)								
123, 143	*(Z)-6-nonen-1-ol*	142	**69(100)**	37(83)	41(62)	55(41)	83(40)	57(31)	39(12)	43(11)	70(6)	67(6)	125(6)	81(5)	32(5)	**123**(4)	71(4)	**143**(4)

[a] confirmed by reference standards
[b] from Lindinger et al. (1998)

Appendix 5.1. FCW choice experiment and consumer sensory test questionnaire.

FRESH-CUT WATERMELON SURVEY AND TASTE TESTING

ID: _____ **Date:**

This questionnaire is about your choice preferences for buying fresh-cut watermelon. Please answer parts 1, 2, and 3. Please note there are no right or wrong answers – we wish to have your honest thoughts. This survey will take no longer than 10 minutes to complete. Thank you for your participation.

PART 1. CHOICE SURVEY

1. How familiar are you with fresh-cut watermelon?

☐ Not at all ☐ Slightly ☐ Moderately ☐ Quite ☐ Very

2. How often do you buy it?

☐ everyday ☐ 4-6 times a week ☐ 1-3 times a week ☐ 1-3 times a fortnight ☐ 1-3 times a month ☐ never

3. When you buy it, do you eat it immediately in one go? ☐ yes ☐ no

If no, how long does it take for you to consume it all? _______ hours or __________ days

4. Do you like the smell of the mint leaves? ☐ yes ☐ no
Do you like its taste? ☐ yes ☐ no
Do you like its look? ☐ yes ☐ no

5. When do you enjoy eating watermelon? ____

Imagine yourself in that situation/ context and consider the following options. Which product are you most likely to buy? Please tick your preferred option per set.

SET 1	OPTION 1	OPTION 2	OPTION 3
Packaging	cup	square	No. I wouldn't buy any of these products.
Mint leaves	yes	yes	
Packed on date	yes	yes	
	☐	☐	☐

SET 2	OPTION 1	OPTION 2	OPTION 3
Packaging	square	square	No. I wouldn't buy any of these products.
Mint leaves	yes	yes	
Packed on date	yes	no	
	☐	☐	☐

SET 3	OPTION 1	OPTION 2	OPTION 3
Packaging	square	square	No. I wouldn't buy any of these products.
Mint leaves	yes	no	
Packed on date	yes	yes	
	☐	☐	☐

SET 4	OPTION 1	OPTION 2	OPTION 3
Packaging	cup	square	No. I wouldn't buy any of these products.
Mint leaves	no	no	
Packed on date	no	no	
	☐	☐	☐

SET 5	OPTION 1	OPTION 2	OPTION 3
Packaging	square	square	No. I wouldn't buy any of these products.
Mint leaves	yes	yes	
Packed on date	no	yes	
	☐	☐	☐

SET 6	OPTION 1	OPTION 2	OPTION 3
Packaging	cup	cup	No. I wouldn't buy any of these products.
Mint leaves	no	yes	
Packed on date	yes	yes	
	☐	☐	☐

SET 7	OPTION 1	OPTION 2	OPTION 3
Packaging	cup	square	No. I wouldn't buy any of these products.
Mint leaves	yes	yes	
Packed on date	no	no	
	☐	☐	☐

SET 8	OPTION 1	OPTION 2	OPTION 3
Packaging	cup	cup	No. I wouldn't buy any of these products.
Mint leaves	yes	no	
Packed on date	no	no	
	☐	☐	☐

SET 9	OPTION 1	OPTION 2	OPTION 3
Packaging	cup	cup	No. I wouldn't buy any of these products.
Mint leaves	no	no	
Packed on date	no	yes	
	☐	☐	☐

PART 2. Please also answer the following questions by placing a tick in the appropriate box or fill in the space.

1. Do you like mint leaves in fresh-cut watermelon? ☐ yes ☐ maybe ☐ no ☐ I never tried but I'd like to try

2. Gender: ☐ male ☐ female

3. Age: ______

4. What is your cultural background?

☐ Australian ☐ Chinese- Australians ☐ Indigenous Australian ☐ Middle Easte

☐ African ☐ European ☐ Irish-Australian ☐ Vietnamese-

☐ American ☐ Filipino-Australian ☐ Italian-Australian ☐ others, pleas

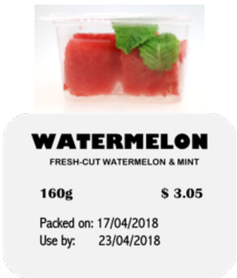
☐ Asian ☐ Greek-Australian ☐ Latin-American ______________

5. If you are willing to participate in our next food innovations project, please provide your contact details below. Thank you.

PART 3. TASTE TESTING[1]. Four (4) samples are given to you. Evaluate one at a time. <u>Indicate your score of liking for each attribute</u> using the **<u>rating scale from 1 to 9, with 1 as dislike extremely and 9 as like extremely</u>**. Tick the box that is appropriate to you. Look at the product's colour and fresh appearance, open the lid and smell, take one or 2 cubes and evaluate crunchiness, taste and flavour. Then evaluate your overall sensory experience for the sample.

	Liking Score								
	1	2	3	4	5	6	7	8	9
Colour									
Fresh appearance									
"smell" freshness									
Firmness of the cubes									
"taste" freshness									
Overall flavour									
Overall liking									

1. After testing, are you going to buy this product? ☐ yes ☐ no
Why or why not? Because of ..... ☐ taste ☐ date info ☐ packaging container ☐ others, please specify ______________________

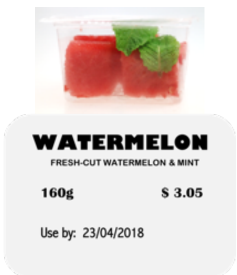


	Liking Score								
	1	2	3	4	5	6	7	8	9
Colour of watermelon cubes									
Colour of mint leaves									
Fresh appearance of cubes									
Fresh appearance of leaves									
"smell" freshness									
Firmness of the cubes									
"taste" freshness									
Overall flavour									
Overall liking									

2. After testing, are you going to buy this product? ☐ yes ☐ no
Why or why not? Because of ..... ☐ taste with mint ☐ date info ☐ packaging container ☐ others, please specify _______________

	Liking Score								
	1	2	3	4	5	6	7	8	9
Colour									
Fresh appearance									
"smell" freshness									
Firmness of the cubes									
"taste" freshness									
Overall flavour									
Overall liking									

3. After testing, are you going to buy this product? ☐ yes ☐ no
Why or why not? Because of ..... ☐ taste ☐ date info ☐ packaging container ☐ others, please specify ______________________



	Liking Score								
	1	2	3	4	5	6	7	8	9
Colour of watermelon									
Colour of mint leaves									
Fresh appearance of									
Fresh appearance of leaves									
"smell" freshness									
Firmness of the cubes									
"taste" freshness									
Overall flavour									
Overall liking									

4. After testing, are you going to buy this product? ☐ yes ☐ no
Why or why not? Because of ..... ☐ taste with mint ☐ date info ☐ packaging container ☐ others, please specify __________________

[1] *Note that participants were given either a set of samples in square punnets or in shaker cups during the informed consumer sensory testing.*

PART 3. TASTE TESTING. Four (4) samples are given to you. Evaluate one at a time. <u>Indicate your score of liking for each attribute</u> using the **<u>rating scale from 1 to 9, with 1 as dislike extremely and 9 as like extremely</u>**. Tick the box that is appropriate to you. Look at the product's colour and fresh appearance, open the lid and smell, take one or 2 cubes and evaluate crunchiness, taste and flavour. Then evaluate your overall sensory experience for the sample.

	Liking Score								
	1	2	3	4	5	6	7	8	9
Colour									
Fresh appearance									
"smell" freshness									
Firmness of the cubes									
"taste" freshness									
Overall flavour									
Overall liking									

1. After testing, are you going to buy this product? ☐ yes ☐ no
Why or why not? Because of ..... ☐ taste ☐ date info ☐ packaging container ☐ others, please specify
____

	Liking Score								
	1	2	3	4	5	6	7	8	9
Colour of watermelon cubes									
Colour of mint leaves									
Fresh appearance of cubes									
Fresh appearance of leaves									
"smell" freshness									
Firmness of the cubes									
"taste" freshness									
Overall flavour									
Overall liking									

2. After testing, are you going to buy this product? ☐ yes ☐ no
Why or why not? Because of ..... ☐ taste with mint ☐ date info ☐ packaging container ☐ others, please specify
____

	Liking Score								
	1	2	3	4	5	6	7	8	9
Colour									
Fresh appearance									
"smell" freshness									
Firmness of the cubes									
"taste" freshness									
Overall flavour									
Overall liking									

3. After testing, are you going to buy this product? ☐ yes ☐ no
Why or why not? Because of ..... ☐ taste ☐ date info ☐ packaging container ☐ others, please specify
____

	Liking Score								
	1	2	3	4	5	6	7	8	9
Colour of watermelon cubes									
Colour of mint leaves									
Fresh appearance of cubes									
Fresh appearance of leaves									
"smell" freshness									
Firmness of the cubes									
"taste" freshness									
Overall flavour									
Overall liking									

4. After testing, are you going to buy this product? ☐ yes ☐ no
Why or why not? Because of ..... ☐ taste ☐ date info ☐ packaging container ☐ others, please specify ______________________

You are finished. Thank you for your participation. We sincerely appreciate your feedback.

Appendix 5.2. Experimental set-up of DCE and informed consumer sensory tests.

Note: Photo reproduction with signed consent from the participants.

Experimental set-up in the supermarkets: (a) Chatswood, (b) Sydney MetCentre, (c) Haymarket and (d) Surry Hills.

(e) Willing participant indicating her choice in one of the choice sets of DCE.

(f) Participant trying out FCW formats during the informed consumer sensory testing

Appendix 5.3. Output of binary conditional logistic regression analysis of FCW formats.

Omnibus Tests of Model Coefficients

	Chi-square	df	Sig.
Step	543.262	4	0.000
Block	543.262	4	0.000
Model	543.262	4	0.000

Model Summary

-2 Log likelihood	Cox & Snell R	Nagelkerke R Square
6341.323a	0.104	0.138

[a] Estimation terminated at iteration number 8 because parameter estimates changed by less than 0.001.

Classification Table[a]

	Predicted choice		
	not	**preferred**	**Percentage**
not preferred	**1570**	**970**	**61.8**
preferred	**639**	**1789**	**73.7**
Overall			**67.6**

[a] The cut value is 0.500.

Variables in the Equation

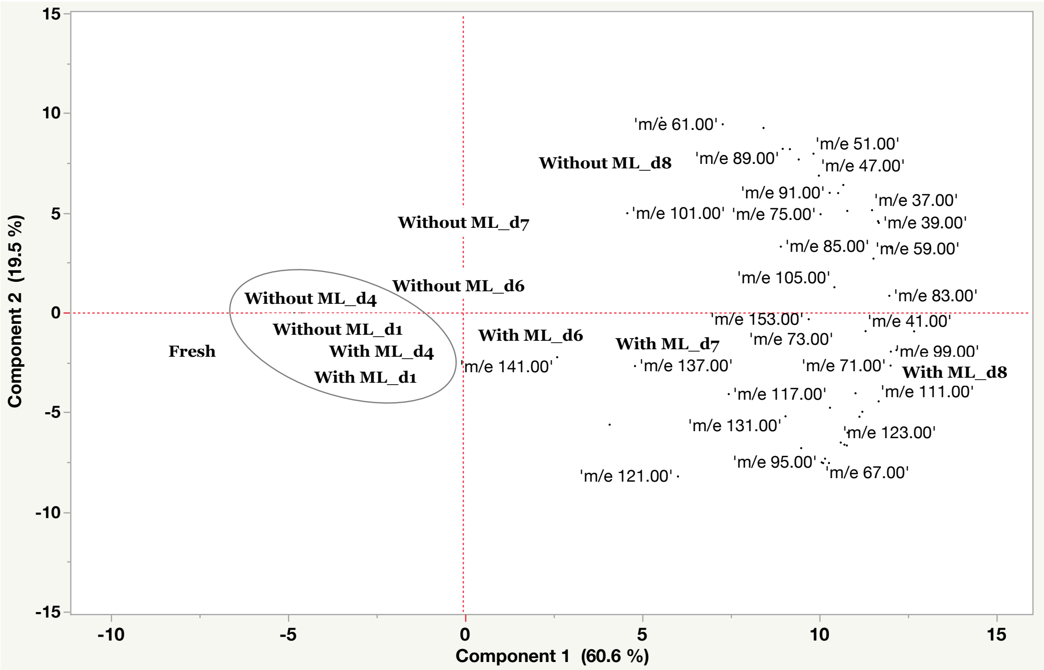
Product extrinsic cues	ß	S.E.	Wald	df	Sig.	Exp(ß)
Price	1.790	4.340	.170	1	.680	5.990
Shelf-life information (1)	1.095	.061	319.297	1	.000	2.990
Shape of the packaging container (1)	.943	.066	202.130	1	.000	2.568
Visual cue (1)	.545	.227	5.774	1	.016	1.724
Constant	-6.826	13.021	.275	1	.600	.001

Conditions: shelf-life information: 1 = with POD, 0 = without POD; shape of the packaging container: 1 = cup, 0 = square; visual cue: 1 = with mint leaves, 0 = without mint leaves

Appendix 5.4. Effects of variable interaction to the liking of FCW formats.

Interactions ($p < 0.05$)	Colour	Fresh appearance	Odour	Firmness	Taste	Flavour	Overall
Usage status X packaging container shape	0.869	0.763	0.686	0.945	0.905	0.707	0.666
Usage status X mint leaves	0.996	0.834	0.864	0.444	0.941	0.754	0.961
Usage status X POD	0.996	0.891	0.994	0.675	0.522	0.768	0.868
Packaging container shape X mint leaves	0.973	0.864	0.869	0.376	0.951	0.919	0.814
Packaging container shape X POD	0.617	0.951	0.892	0.667	0.743	0.825	0.952
Usage status X packaging container shape X mint leaves	0.149	0.159	0.350	0.585	0.412	0.201	0.221
Usage status X packaging container shape X POD	0.955	0.839	0.861	0.619	0.605	0.415	0.432
Usage status X mint leaves X POD	0.740	0.965	0.965	0.940	0.744	0.964	0.714
Packaging container shape X mint leaves X POD	0.392	0.683	0.680	0.680	0.204	0.451	0.383
Usage status X packaging container shape X mint leaves X POD	0.614	0.975	0.876	0.886	0.795	0.833	0.886

Appendix 5.5. PCA biplot of volatiles from FCW samples for consumer sensory test.



Conditions:
ML = mint leaves; d= days of storage at 3 °C
Sample signature: With ML_d1 = fresh-cut watermelon (FCW) with mint leaves stored for 1 day at °C

Note:
Samples encircled were the samples used for the informed consumer sensory testing in reference to the volatile compounds of the freshly cut watermelon (Day 0). This information showed that the samples stored up to four day were comparable to the freshness of a fresh sample and therefore, could be treated equally when subjected to the consumer sensory testing.

Appendix 6.1. Personal communications with partner industry regarding innovation outcome

Final requests for the Fresh-cut fruit quality and consumer acceptance project with ARC

MO Martina O'Sullivan <martina.osullivan@perfection.com.au>
Tue 2/18/2020 9:07 AM
To: Michelle Louise Mendoza-Enano

Hi Michelle,

Forgive the delay, things don't quieten down in Perfection and its particularly busy at the moment.

For 302360 Watermelon and Mint 200g sales during the period you've mentioned have been - $400,352.29. In the financial year prior we didn't have an active watermelon sku within the range.

There was no attachment to your original email but familiar with the shaker cup 160g. Below are square version, are these what you are after?

Kind Regards,

Martina O'Sullivan
Innovation Manager
Perfection Fresh Australia Pty Ltd
P +612 9763 1877 | F 02 8079 6848 | M 04

MO Martina O'Sullivan <martina.osullivan@perfection.com.au>
Tue 2/18/2020 10:04 AM
To: Michelle Louise Mendoza-Enano

105x105x55 Punnet .pdf
Saved to OneDrive

Hi Michelle,

Please see drawing attached.

Previous ranging was FY17/18 and supply was very sporadic eg, we sold weeks 5-11, week 17 , week 42 and week 46. Sales total $68,124.

Kind Regards,

Martina O'Sullivan
Innovation Manager.
Perfection Fresh Australia Pty Ltd.
Ph: +612 9763 1877 | Fx: 02 8079 6848 | Mb: 04
Level1, 7 Underwood Road, Homebush NSW 2140.

Appendix 6.2. Evidence of new FCW format in the supermarkets.

Note: Photo reproduction with signed consent from the participants.

(a) New formats of FCW at Woolworths supermarket in Sydney, Australia.

(b) Participants of consumer survey and in-depth interviews bought the new FCW format.