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Distinctive physical attributes of New Zealand agri-food exports

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EXECUTIVE SUMMARY

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A framework has been developed to aid exploration of the ways that physical properties affect consumer perception and choice of food. One of the primary ways that physical properties of food influence consumers is through the quality of the eating experience, which we can perhaps define as all those characteristics of a food that lead a consumer to be satisfied. Consumer perception of eating quality is determined according to human senses and categorised into flavour (aromatics, tastes and chemical feeling factors) and texture (mechanical, mouthfeel and other factors) as well as psychological factors (e.g. appearance and aroma) that influence expectations of the sensory experience. For many foods, the perceived sensory experience evokes not only liking for the food, but also more complex emotions and the recognition of the most appropriate places and situations to use the food. Another set of physical product attributes affects the way consumers are able to ensure the food fits into their food provisioning (the acquisition, preparation, cooking, eating and disposal of food). Food convenience (the need for preparation and clean-up, messiness during consumption, ease of storage in the home, variety of different uses, suitability for all the family and availability in many shops over the entire year), in particular, is often determined by the physical properties of foods. Furthermore, physical properties of foods that cause immediate human digestive responses are considered – for example, relief from constipation. Using this framework, five types of agri-food exports are considered: wine, apples, kiwifruit, meat and seafood. The physical properties of New Zealand agri-foods often provide distinctive differentiation of our products from those produced by the rest of the world. For example, Oz Clark's description of Marlborough Sauvignon blanc wine: *"...No previous wine had shocked, thrilled, entranced the world before with such brash, unexpected flavours of gooseberries, passionfruit and lime, or crunchy green asparagus spears ... An entirely new, brilliantly successful wine style that the rest of the world has been attempting to copy ever since*". In many cases the distinctive nature of New Zealand's agri-food exports are derived from the way agriculturalists are able to manage genetics and environmental interactions for an optimal outcome. Human management of the production system, supported by science, gives New Zealand its point of differentiation.

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1 FRAMEWORKS AND DEFINITIONS

1.1 Definition of eating quality

It is important to have a framework to define what is meant by both ‘quality’ and ‘physical attributes’ before considering how New Zealand’s export offering is distinctive. Food quality can be defined as all those characteristics of a food (not just the sensory characteristics) that lead a consumer to be satisfied with the product (Cardello 1995). From a consumer-centric perspective, quality is sometimes measured according to enjoyment of the experience of eating or drinking a particular food or beverage. Therefore, ‘eating quality’ perhaps can be defined by extension from Cardello (1995) as all those characteristics of a food that lead a consumer to be satisfied with the eating experience.

Essentially, the measurement ‘eating quality’ can, in this simplest form, be obtained by asking: how much do you like this product? The answer can be collected using a range of established scales (Lim 2011). But, in order to determine which sensory characteristics of a food influence liking, we must turn to the flavour-texture framework described in Table 1.

Table 1. Categories and sensory definitions of the physical attributes that influence human perception of eating quality.

Definitions of flavour, texture and psychological factors

- **Flavour:** The impressions perceived via the chemical senses from a product in the mouth. Defined in this manner flavour includes:
  - The aromatics, i.e. olfactory perceptions caused by volatile substances released from the product in the mouth via the posterior nares (nasal passage)
  - The tastes, i.e. gustatory perceptions (salty, sweet, sour, bitter) caused by soluble substances in the mouth
  - The chemical feeling factors that stimulate nerve ends in the soft membranes of the buccal and nasal cavities (astringency, spice heat, cooling, bite, metallic flavour, umami taste).

    (Definition according to Meilgaard et al. 2007; after Caul 1957).
- **Texture:** The sensory manifestation of the structure of the food and the manner in which this structure reacts to applied forces, the specific senses involved being vision, kinaesthesia, and hearing. [Note that kinaesthesia is the sensation of presence, position, or movement resulting from stimulation of sensory nerve endings (or mechanoreceptors) in muscles, tendons and joints]. Texture is separated into three broad categories:
  - Mechanical properties (e.g. hardness, elasticity)
  - Mouthfeel / geometric properties (e.g. smooth, gritty)
  - Fat / water content (e.g. in fruit this is juiciness).

    (Definition by Szczesniak 1990 and Szczesniak 1963).
- **Psychological factors:** Consumers’ perception of flavour are often influenced by their expectations of what they are about to experience (e.g. the addition of red food colouring to white wine results in consumers describing wines as having berryfruit and plum flavours, even though there has been no physical change in volatiles or tastants):
  - **Appearance:** (e.g. colour of skin = ripeness, colour of the flesh = red v. green flavours)
  - **Odour/Aroma:** The aromatics, i.e. olfactory perceptions caused by volatile substances in the environment or perceived by sniffing the product.

The definitions in Table 1 draw heavily on knowledge of the biology of the human senses. It is important to recognise that all humans differ in sensory acuity – to the extent that it is certain that each individual lives in their own flavour world (McRae et al. 2013). For example, it has been demonstrated that humans differ genetically in terms of ability to perceive both aromatic compounds and tastants (McRae et al. 2013; Shen et al. 2016). McRae and co-workers (2013) found that, for the compounds they studied, the high genetic variability among individuals occurred across many different ethnicities, but that there was no systematic differences between ethnicities. As an aside, this study suggests that food culture rather that genetics of flavour perception defines what foods are appropriate to consume.

1.2 Assessing distinctiveness of eating quality

Distinctive, in this context, implies foods are premium and recognised as being uniquely associated with New Zealand. There is ongoing research on how to assess the level of uniqueness as associated with different flavours (Cardello et al. 2016). There is a paradox associated with being unique: the more unique a concept is, the greater chances of success; however, if the concept exceeds a threshold is will become less successful (Cardello et al. 2016; Figure 1).

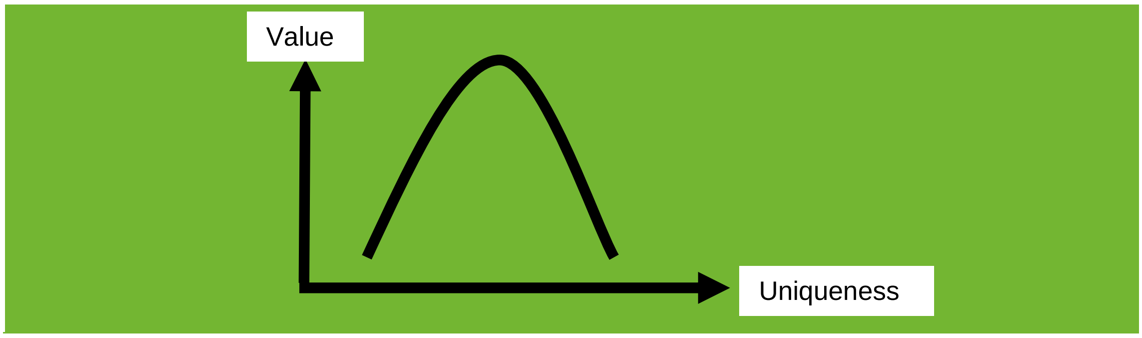

Figure 1. Paradox between increasing uniqueness and value.

Plant & Food Research's first study on uniqueness focussed on consumer perceptions of beer (Cardello et al. 2016) and measuring uniqueness of food is a topic of on ongoing interest (Jaeger et al. 2016, 2017). Samples of beers were presented to consumers in black glasses to obscure any cues to quality associated with appearance (Figure 2; also there was no information on brand). The responses were therefore a consequence of the sensory properties of beers as defined in Table 1, but predominantly responses to flavour. The research is founded on our framework that understanding of food consumption needs to consider the person, the product and the place of consumption (Jaeger et al. 2011a).

The data demonstrated that 'familiar' and 'unique' represent opposing poles along the same food and beverage continuum (Cardello et al. 2016). Consumers' attitudes, emotional responses and their assessment of potential consumption situations was affected by where products were positioned along this continuum. There were beers that consumers identified as being familiar, easy to drink and somewhat boring, which would be consumed at home, barbeques and sports events to quench one's thirst. There were other unique beers that stimulated curiosity and excitement, and which would be consumed on special occasions. On the other hand some of the beers judged as unique were represented by extreme and slightly disturbing flavours (that made many consumers feel tense and bothered) and likely to be consumed only to impress other beer drinking friends.

These results highlight that sensory-based consumer science is progressing beyond simple measures of eating quality as measured by liking. Rather there is an increasing appreciation that emotional measures of interaction with foods and beverages are needed. One of the more successful tools implemented by Plant & Food Research has been the use of the emotional circumplex in questionnaires (Cardello et al. 2016; Figure 3). The circumplex uses a horizontal dimension (unhappy/dissatisfied to happy/satisfied), which is akin to standard dislike to like continuum used in standard studies. The vertical dimension from passive/quiet to active/alert allows a more nuanced understanding of the emotions associated with eating quality. There are other ways of soliciting emotions associated with food consumption such as the Esense CATA list, but the circumplex is a simple and intuitive additional dimension to liking.

Figure 2. Beers served in black glasses as part of research on uniqueness associated with flavour.

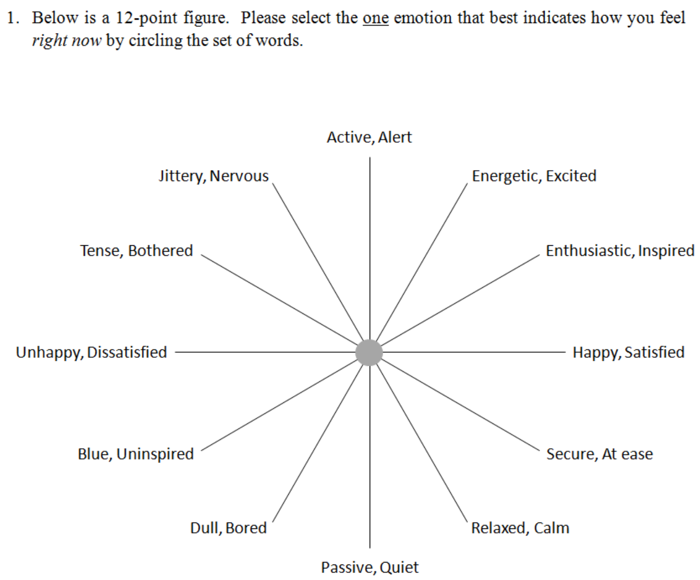

Figure 3. Emotional circumplex is a simple method for understanding emotions evoked during food and beverage consumption.

1.3 Other consumer needs associated with physical attributes

There are a number of ways the physical attributes of foods and beverages that affect consumers' interactions extend beyond those associated with eating quality. A good starting point is to consider the food megatrends that have been consistently highlighted over a number of decades: eating quality, convenience and health.

Food provisioning occurs as a continuous and cyclic process, which includes the acquisition, preparation, cooking, eating and disposal of food (Marshall 1995). Within families the key decision-maker, often a woman, is subject to severe time pressures to make good food choices for themselves, their family and friends (Bava et al. 2008). This increasing time pressure has driven consumers to search for convenience in the foods they purchase. An example of an agri-food for which physical attributes contribute to convenience is fruit. Fruit convenience generally means: (1) no preparation or clean-up (e.g. utensils not required, not messy to eat), (2) handles well (e.g. little bruising, keeps long), (3) variety of uses (e.g. breakfast, snack, dessert), (4) suitable for the entire family (e.g. liked by adults and children), (5) high availability (e.g. long season, available in many shopping outlets) (Jaeger 2003). The physical properties of fruit skins (e.g. peelable, edible and those that require consumers to cut and scoop flesh) and the biological properties of the flesh and how it softens (e.g. during long-term commercial storage and in the home) determine many of these aspects of convenience (Harker et al. 2007).

Consumers are showing increasing interest in foods that provide health and wellness benefits. There are two types of food-related health and wellness benefits: (1) those that provide protection from future illnesses such as cardiovascular disease and cancer and (2) those that provide an immediate benefit (Mellentin 2009), for example relief from constipation. For this review, we are assuming that the former are credence attributes because the consumer is required to believe they will deliver a future benefit whereas the later are relevant, because consumers can 'feel the difference' within a period of weeks if not days. Kiwifruit is an example of a New Zealand food that is well recognised by consumers for its ability to relieve constipation and recently Zespri has gained the first substantiated health claim under FSANZ (Food Standards Australia & New Zealand) regulations. The claim substantiates: *'that consumption of two Zespri green kiwifruit (Actinidia deliciosa var Hayward) daily improves bowel motion frequency in constipated individuals by >1.5 complete spontaneous bowel motions / week'*. While the claim is about the biology of gastro-intestinal function, it is important to recognise that a well-functioning gut is recognised by consumers as reducing worries, and improving relaxation, mood, confidence and freedom (Gamble et al. 2013). The clinical benefits in reducing constipation are a consequence of the physical and chemical characteristics of kiwifruit (Rush et al. 2002; Gearry et al. 2017).

1.4 Sources of biological variability

The success of New Zealand's agri-food sectors is dependent on the biology of the plants and animals. Generally, but not exclusively, these are organisms that have been introduced to New Zealand. From a biological perspective, the framework for success is founded on the genetics of the plants and animals, the way these genetically based attributes interact with the New Zealand environment and, finally, the way agriculturalists are able to manage genetics and environmental interactions for an optimal outcome.

New Zealand agricultural industries have invested in the acquisition and development of genetic resources and the improvement of these genetics through breeding. The genetics that we have accessed represent the building blocks that determine productivity, environmental impact and eating quality. Industries have adapted these genetics to New Zealand environmental conditions and in doing so have made them unique to our country. Furthermore, attempts to export these genetics to other countries have not always been successful; for example, the New Zealand bred gold-fleshed kiwifruit failed to thrive in California. A step beyond the improvement of imported genetics is New Zealand's access to its own indigenous genetics – for which the most significant economic outcomes are associated with finfish and seafood.

The New Zealand climate is within a temperate through to subtropical zone and this determines the range of plants and animals that can be successfully grown. Another environmental advantage is New Zealand's location in the Southern Hemisphere. This means that seasonal production occurs on an alternative phase with major competitors in the Northern Hemisphere. Within New Zealand there is considerable pressure on availability of land of appropriate soil type and micro-climate. The linking of food production to the physical environment (soil conditions, rainfall, microclimate) is described as terroir by the wine sector and is held in high esteem for consumers of distinctive products of provenance. Such viewpoints are attractive to many agri-food sectors although the extent that this notion of terroir (as understood by consumers) is supported by science remains ambiguous.

Arguably, the most important component of these three components of biological variability is the ability of industry to innovatively manage the agricultural systems. For many of our agri-food industries the advantages of the genetics (of the improved plants and animals) and environment only get part of the way. New Zealand's successful industries have consistently found ways to improve productivity, sustainability and eating quality through the way they manage farms, orchards and vineyards.

1.5 Relevance of framework and definitions

To summarise, the physical attributes that will mostly be the focus of this review are those perceived as sensory characteristics (flavour and texture) that invoke emotional responses from consumers during eating and drinking. Differentiation arises when the unique combination of flavours and textures differentiates New Zealand products from other agri-foods in a way that also invokes positive emotions such as might sustain association with exclusive consumption situations. The New Zealand's agri-food industries have achieved these distinctive properties in their export foods and beverages through the way they innovate and manage genetic and environmental variability.

This review focusses on scientific publications accessible via searches of the web of science and has not considered the popular, technical or industry literature.

2 EXAMPLES OF DISTINCTIVE NEW ZEALAND FOODS AND BEVERAGES

2.1 Marlborough Sauvignon blanc wine

In describing Marlborough Sauvignon blanc, the influential wine writer Oz Clark wrote: *"...No previous wine had shocked, thrilled, entranced the world before with such brash, unexpected flavours of gooseberries, passionfruit and lime, or crunchy green asparagus spears ... An entirely new, brilliantly successful wine style that the rest of the world has been attempting to copy ever since*" (Clark 2002). This statement regarding the uniqueness of the flavour is supported by an anecdote from Dr Mike Trought who took a bottle from an early vintage to share with oenologists at the University of California, Davis. They commented that if they had known consumers would buy wine that tasted like this, they would have made it years ago! More concrete evidence that New Zealand has set the standard was provided in blind tastings when 23 French experts selected Marlborough over French Sauvignon blanc as representing a good example of what a Sauvignon blanc wine should be (Parr et al. 2010). The global wine industry involves a number of multinational companies and they often focus on exclusive brands that represent a region by style interaction – in this manner, a number of companies select Marlborough as the source of their Sauvignon blanc. Scientific evidence that Marlborough Sauvignon blanc has a distinctive flavour has been provided in a study by Lund et al. (2009).

Lund and coworkers (2009) developed a vocabulary and reference flavours (also known as a wine flavour wheel; Figure 4) which was used by 14 sensory panellists (each with more 70 hours training) to assess Sauvignon blanc. These trained assessors then evaluated 52 Sauvignon blanc wines from six countries (Figure 5).

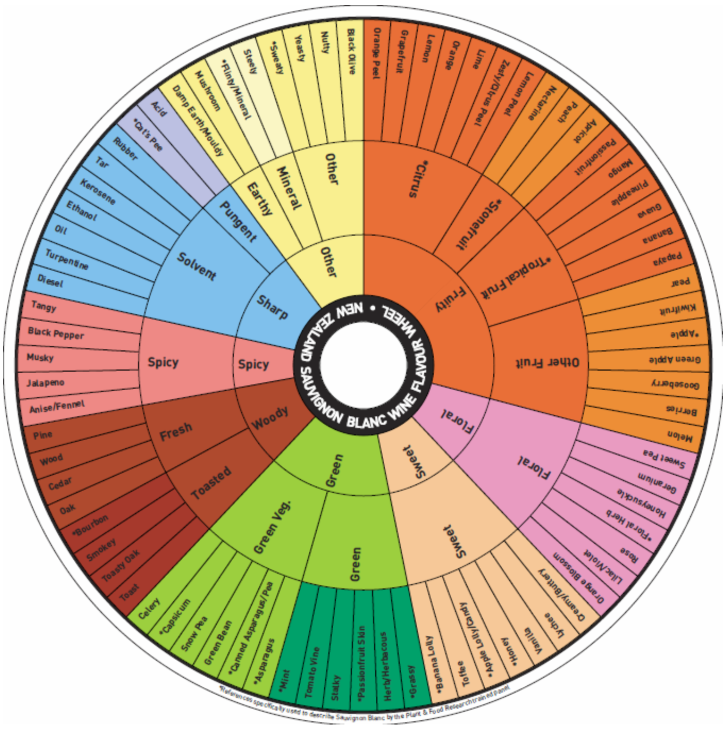

Figure 4. Flavour wheel for use in the sensory assessment of Sauvignon blanc wine.

Figure 5. Assessing the flavour of 52 Sauvignon blanc wines from six countries.

The sensory assessments established that Marlborough Sauvignon blanc was differentiated from that produced in other New Zealand regions (Hawke's Bay and Wairarapa) as well as from that produced in Australia, France, South Africa, USA and Spain. The Marlborough wine tended to be higher than other Sauvignon blanc wines in terms of sensory attributes 'stonefruit', 'apple', 'tropical', 'passion fruit skin/stalk', 'capsicum', 'sweet sweaty passion fruit' and 'fresh asparagus' and lower in sensory attributes 'bourbon', 'flinty/mineral' and 'canned asparagus' (Lund et al. 2009 – Figure. 1). Each of these descriptors was defined during training using a reference chemical or food (Lund et al. 2009).

There has been considerable interest in the chemistry that contributes to these differences in sensory experience (Goode 2012). The current understanding is that the tropical and vegetable flavour notes are associated with a series of sulphur-containing compounds called thiols, which include: mercaptohexanol, 3-mercaptohexyl acetate and 4-mercapto-4-methylpentan-2-one. These thiols along with another category of compounds, the methoxypyrazines, contribute to the distinctive varietal characteristic of New Zealand Sauvignon blanc. The methoxypyrazines (2-methoxy-3-isobutylpyrazine, 2-methoxy-3-isopropylpyrazine and 2-methoxy-3-secbutylpyrazine) are responsible for the green flavour notes. The methoxypyrazines are present in the grape at harvest, but the thiols exist in a glycosylated form, which is flavourless. Rather, it is that action of yeasts during fermentation that are responsible for the conversion of the compound to a flavourful state.

The role of New Zealand and Marlborough terroir in creating this distinctive wine is most important from a marketing and science perspective. There is variability among wines regarding the extent that they meet expectations of what is a typical Sauvignon blanc wine, even within the Marlborough region (Parr et al. 2007). The concept of terroir is anchored in a perspective that the location and region where grapes are grown are directly responsible for flavour and texture along with the human decisions on the management of the vines, grape harvest and winemaking. Recent projects have sought to use metabolomics approaches to understand variability in wine chemistry across Marlborough and other wine-growing regions (Pinu et al. in preparation). Over three vintages, samples of juices were collected from wineries and made into wine using a standard fermentation protocol, and following this 326 juices and 380 wines were subjected to an analysis of metabolites using a variety of analytical tools. These data were able to be linked back to the location of individual vineyards and through this to soil types, rainfall, temperature (e.g. growing degree days) and vine management.

The data analysis is ongoing, but clearly demonstrates that seasonal variation is more prominent than regional difference in both grape juices and wines and highlights that variation between the juices and wines is often associated with different wineries. There is a considerable body of research and continuing investment in understanding vineyard management and winemaking practices that influence the flavour of Sauvignon blanc (Goode 2012). The value of the project above is that it is anchored in commercial practice (Figure 6). The study supports the suggestion that it is the human management of the production system, supported by science that is New Zealand's point of differentiation.

Figure 6. Harvesting and transportation of grapes to winery in Marlborough.

2.2 New Zealand's distinctive apples

The New Zealand apple industry has a reputation for developing new cultivars of apple, providing the world with 'Gala', 'Royal Gala' and 'Braeburn' (Brook 1999). Government-supported apple breeding programmes have followed up these successes with the creation of new generations of cultivars that are protected by patents (Plant Variety Rights) and licenced to commercialisation partners. This new generation of protected cultivars includes the Pacific series ('Sciros'/Pacific Rose®, 'Sciearly'/Pacific Beauty® and 'Scired'/Pacific Queen®), 'Scifresh'/Jazz®, 'Scilate'/Envy®, 'PremA17'/Smitten® and 'PremA96'/Rockit® to name but a few.

Many of the original public cultivars are now grown overseas, with production exceeding that in New Zealand – for example, 'Gala' has replaced the iconic 'Red Delicious' as the dominant apple crop grown in Washington State, USA. The patents for the newer 'club' cultivars have allowed production to be controlled (by limiting the number of growers) and thereby ensuring that supply does not exceed demand. This business model has allowed companies to make long-term investment in developing brands based on new cultivars, of which the best example is the Pink Lady®.

New Zealand's new cultivars deliver distinctive and superior eating quality, and convenience is an increasing important point of difference. Arguably these innovative new cultivars have ensured that the New Zealand apple industry has maintained its profile within the supply chains and retailers and allowed expansion of sales in international markets. In the following paragraphs, we present the the science that demonstrates what is distinctive about these new cultivars.

For perishable products such as apples, comparisons of New Zealand grown goods with those from the Northern Hemisphere is problematic. The off-set in seasons means that one of the sets of apples is always less fresh than the other and direct comparison of equivalent stage of storage is impossible. Part of the problem is the poor capacity of humans to provide consistent measures of eating quality over a long period of time without being influenced by changing availability of foods across a year. In other words, what happens in the environment that consumers are living in may influence their responses at any one time. Nevertheless it is possible to establish the distinctive characteristics that differentiate cultivars and determine which of these characteristics can be manipulated to improve eating quality (Daillant-Spinnler et al. 1996; Harker et al. 2005; Bonany et al. 2014).

Before discussing these results it is useful to introduce the methodology generally used to establish the distinctive features of flavour and texture. In the past the presumption was that one needed to separate collection of consumer preference data on liking from the collection of analytical measures of perceived texture and flavour. This was based on evidence that asking consumers to quantify flavour and texture attributes would introduce bias into their more emotional and intuitive assessment of liking – e.g. the liking scores for different recipes of chocolate mousse changed when participants were also asked about the intensity of chocolate and milky flavour (Earthy et al. 1997). Thus, samples from treatment are generally assessed by two types of panel: a consumer panel to assess liking and a trained panel to assess sensory attributes. More recent techniques have overcome the need for separate panels.

Preference maps are based around the responses collected from consumers. Imagine that we have four treatments, A, B, C and D, and two consumers. The first consumer ranks the products in order of liking as 1,2,3 and 4 whereas the second consumer's ranking is 4,3,2 and 1. In this simple example, we know nothing about the flavour, but we can perhaps assume there is a linear change in flavour in which the two consumers have opposing preference. If instead of two consumers we have a 100 of them and they provide quantitative rather than ranking of liking we can creating a map of consumer liking upon which we can project the location of treatments and the sensory attributes that are associated with particular directions on the map.

The first published apple preference map was constructed based on British consumers tasting 12 cultivars from the Southern Hemisphere (South Africa and New Zealand; Daillant-Spinnler et al. 1996). New Zealand-grown cultivars included 'Royal Gala', 'Braeburn', 'Fuji', the selection GS330 (Sciearly/Pacific Beauty®), 'Fiesta' (UK-bred cultivar) and 'Aurora'. The study concluded that consumer preferences were generally for sweet, crisp and juicy apples with a significant group preferring sweet and high acid apple and another group preferring sweet and low acid apples. The cultivars that defined the extreme limits of these preferences were New Zealand-grown 'Fuji' (sweet and low acid) and New Zealand-grown 'Braeburn' (sweet and high acid). Following on from this study in Britain, New Zealand-based scientists constructed a preference map using recent Plant & Food Research (then HortResearch) selections along with some standard cultivars (Figure 7; Harker et al. 2005). In Figure 7 (the plots represent the same product space and are presented as two graphs for clarity) it can be seen that consumers (red points) are scattered across the product space, but tend to aggregate to the left-hand side rather than the right-hand side of the plot. The cultivars that most likely meet these consumer needs are HortResearch cultivars 'Sciros'/Pacific Rose™, 'Scired'/Pacific Queen™ and 'Scifresh'/Jazz™. The selection RG x B ('Royal Gala' crossed with 'Braeburn') meets the distinct needs for sweet and high acid apples represented by consumers clustered at the top of the graph, which was identified as a distinct product opportunity by Daillant-Spinnler et al. (1996). There is a general caution that the location of cultivars in any of these preference maps is also a consequence of the place where it was grown, the way the crop was managed and how long it was stored (e.g. see Harker et al. 2008; Jaeger et al. 1998).

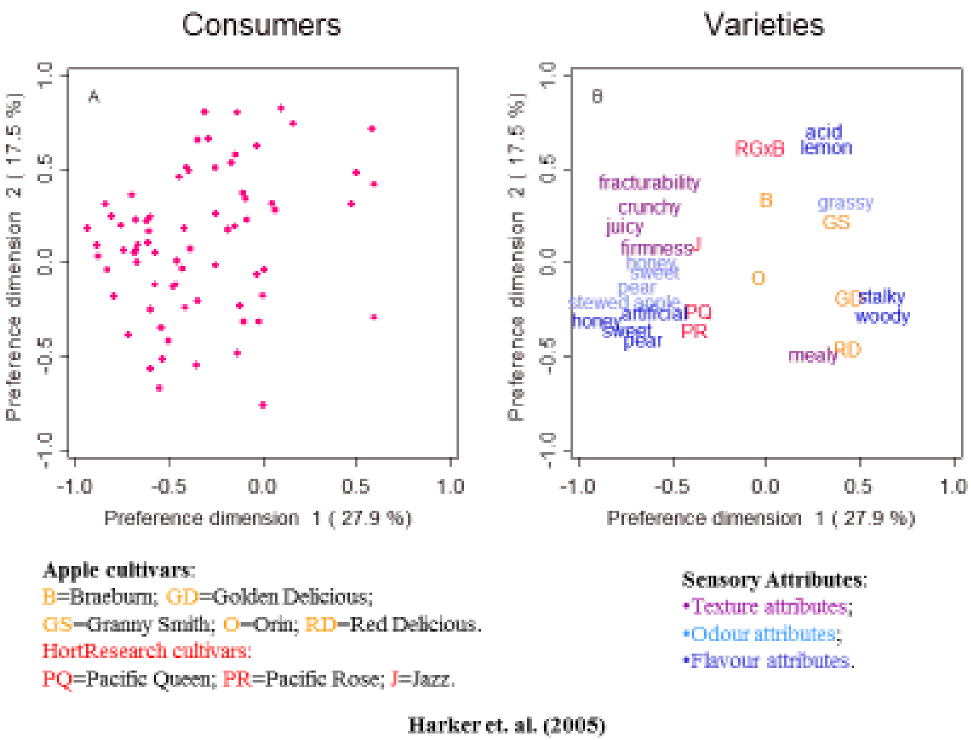

Figure 7. Apple preference map for New Zealand-grown apples featuring then new genotypes Pacific Rose®, Pacific Queen® and Jazz®.

2.3 Kiwifruit: the world's most recent successful new fruit

Kiwifruit are arguably the newest of globally traded perennial fruit crops. Seeds collected in China were introduced to New Zealand in 1904 (Ferguson 2004). The green-fleshed fruit was originally known, in New Zealand, as the Chinese gooseberry. The start of the global sales of Chinese gooseberries was in 1952 when a small trial shipment was sent from New Zealand to the United Kingdom (Ferguson & Bollard 1990). The name kiwifruit was first used in the 1960s in an attempt to differentiate them from gooseberries, which were considered in some export markets to be common fruits (Ferguson & Bollard 1990). The kiwi (*Apteryx australis*) is an indigenous flightless bird with brown feathers that is an emblem of New Zealand and also the colloquial name for New Zealanders.

As with apples, there has been a successful breeding programme that has focussed on diversifying the products range, releasing sweeter and yellow-fleshed cultivars 'Hort16A' and 'Zesy002' that are protected by patents and owned by Zespri.

Preference maps were constructed for kiwifruit in the early 2000s (Jaeger et al. 2003; Wismer et al. 2005). Wismer et al. (2005) recruited a Japanese ethnic panel in Auckland to assess kiwifruit alongside New Zealand consumers. The responses of Japanese and New Zealand consumers were relatively similar at the level of precision provided with this scale of study. Overall, the study demonstrated that the product space was driven by preferences for sweet, soft, juicy kiwifruit with separation into four groups: (1) consumers who like both green- and yellow-fleshed kiwifruit, (2) those that prefer sweet tropical flavours of yellow-fleshed kiwifruit, (3) those who prefer the sweet and grassy flavours of green-fleshed kiwifruit, and (4) those who regularly eat kiwifruit, but don't seem to like the flavour of any kiwifruit (Wismer et al. 2005). The latter group is speculated as eating kiwifruit for the health benefits they provide.

With both green-fleshed and yellow-fleshed kiwifruit, it is possible to predict eating quality (as defined by consumer liking scores) at harvest through the measurement of dry matter content (Harker et al. 2009; Jaeger et al. 2011b). This is an important quality-measurement tool, because kiwifruit are harvested when they are hard, starchy and unpalatable. This is necessary to ensure that they are firm enough to survive during grading operations and handling throughout the supply chain as well as to provide good storage potential. During storage and ripening the fruit softens, the starch is converted to sugars and biosynthesis of volatiles are induced (Richardson et al. 1997; Wang et al. 2011).

The New Zealand launch of the yellow-fleshed cultivar 'Hort16A' in 1998 provided an opportunity to investigate how consumers viewed the differentiation of kiwifruit into two distinct product types. Despite the horticultural novelty of 'Hort16A', New Zealand consumers thought it was only slightly more novel than green-fleshed kiwifruit (Harker et al. 2005).

Kiwifruit are a useful product to consider how physical characteristics can influence the way foods fit into consumers' lives. Kiwifruit are inconvenient as fruit and do not fit easily into consumers lives (Harker et al. 2007). They require utensils to eat; a knife to cut in half and spoon for scooping or a spife (combination knife and spoon) and without these are messy to eat (Jack et al. 1997). For some consumers, they are difficult to judge when they are eating ripe (Harker et al. 2007). In the past they were often sold in an unripe state and consumers often needed to leave them for days if not weeks before they were soft enough to eat. For many consumers, this meant that they would forget about the fruit and end up throwing it away when it deteriorated beyond the state that was reasonable (Campbell et al. 2008). Other consumers have commented that the appearance is boring and reminiscent of potatoes or onions (Harker et al. 2007). Women who successfully incorporate kiwifruit into their diet tend consume the fruit at breakfast with cereal and tea or coffee – it is rarely eaten when consumers are on the move (Bava et al. 2012).

The shortcomings described in the previous paragraph should be re-stated as opportunities to improve kiwifruit. Kiwifruit belongs to a genus that includes great diversity in physical characteristics. This diversity has been used in breeding to develop new cultivars and to progress towards more convenient concepts of kiwifruit. The most successful of these are grape-sized kiwifruit with edible skins that are marketed as kiwiberries and include the cultivar 'Tahi', which fits into a more diverse set of usage situations and is more suitable for children (Amos 2007; Jaeger et al. 2005). There has also been some progress towards creating kiwifruit with peelable skins (Harker et al. 2011). Furthermore, with conventional kiwifruit the industry takes great effort to provide the fruit into the market at eating ripeness.

2.4 New Zealand's distinctive beef and sheep meat

Progressing to a discussion on meat, two factors arise. First, the topic is further from my own area of expertise. Second, the product takes us from foods that are likely to be consumed on their own (beer, wine and fruit) to foods that are more likely to be cooked by consumers as a component in a meal. Thus, the eating quality is as much influenced by consumers' decisions regarding how the meat is cooked, what herbs, spices and sauces are used in preparation and as garnishes with the meat, and the influence of other components of the meal on perception of the texture and flavour of the meat – e.g. when meat and mashed potato are simultaneously placed in the mouth. In this regard, eating quality is as much in the hands of the consumer as it is the consequence of place where it was grown and management of quality through the supply chain. It is likely that New Zealand meat is distinctive as demonstrated for example by its unique metabolomic fingerprint (Jung et al. 2010). However, we are uncertain of the extent that this unique metabolomics profile might translate to a distinctive sensory experience.

A product-centric approach has been used by scientists researching meat and involves standardising the cut of meat, preparation and cooking so that different production systems can be compared. Generally these studies involve blind tasting of meat (i.e. without information about the product or production system), which is undertaken by trained panels (e.g. Frank et al. 2016), expert panels (e.g. Maher et al. 2004 a & b) and consumer panels (e.g. Realini et al. 2013). When consumer panels have been used there is a risk regarding the ecological validity, because consumers are tasting samples rather than meals. There seems to have been little use of newer consumer centric approaches discussed in earlier sections, although confirmation of this would require a broader review than is the focus of the current report.

International research has focussed on identifiable elements of the production system such as breed, geographical origin, grass versus gain feeding of cattle and the role of some elements of pastures in the texture and flavour of meat. The results tend to be somewhat contradictory; for example, Maher et al. (2004a) found no difference in sensory properties of beef meat of Holstein-Fresian cattle of New Zealand and European/American descent as well as Belgian Blue x Holstein-Fresian cattle. Frank et al. (2016) found that Wagyu cattle provided meat that was more intense in flavour and higher in juiciness and tenderness than Angus cattle and also that the effect of feed (grass versus grain) was small after an adjusting for fat levels. However, Maughan et al. (2012) found grass-fed compared with grain-fed Angus cattle provided steaks that were higher in flavour attributes barny, bitter, gamey and grassy and lower in juicy and umami. Furthermore, US consumers preferred the steaks from the grain-fed (liking score ~ 'like moderately') over those from grass-fed cattle (liking score ~ 'like slightly'; Maughan et al. 2012). Realini et al. (2013) found that Uruguayan Hereford steers fed on grass were more liked by consumers than steers fed on concentrates and hay. In a study on lamb meat, Font i Furnols et al. (2011) found that pasture-fed animals produced meat that was less liked than animals fed diets that included the use of concentrates. However, this difference in liking was significant for consumers recruited in Spain and Britain, but not France. There is a paucity of this type of study focussing on New Zealand-produced meat that is easily accessible in the scientific literature. Furthermore, the translation of this information to the New Zealand situation is not straightforward because genetic x environment interactions often vary by country and consumer responses are market-dependent and often relate to food culture and familiarity with certain flavours. It is possible that the information on consumer perceptions of the flavour and texture of New Zealand meat is in industry reports not reviewed as part of this report.

2.5 New Zealand's distinctive seafood

New Zealand seafood and marine fish represent distinctive and unique foods for the simple reason that they are native, if not endemic, to our maritime economic zone. They include foods such as green-lipped mussel, Bluff oysters. Orange roughy, hoki, and hake, and also introduced species such as farmed Chinook salmon, also known in New Zealand as King salmon.

These foods are subject to issues discussed previously in that they are frequently cooked and eaten as a component of a meal rather than as an individual item, although there are well-known exceptions. As with the previous section on meat, there are no obvious studies that attempt to compare eating quality of these New Zealand seafood and fish with those from other parts of the world. Rather, the few studies in the academic literature focus on variability in eating quality associated with geographic region and season (Phillips et al. 2010a,b), the effect of diet for organisms used in aquaculture (Preece 2006), and optimising supply chains to deliver eating quality (Fletcher et al. 2002, 2003).

A trained panel evaluation of the roe of Kina (sea urchin, *Evechinus chloroticus*) demonstrated differentiation in flavour such that roe from males was sweeter with a dairy flavour and roe from females was bitter with an herbaceous and metallic flavour (Phillips et al. 2009). Comparisons between roe from kina growing by the North and South Islands demonstrated that the roe from the South Island of New Zealand were rated as being higher in sensory attributes volume, edge and flaps, dairy odour, sweet taste, dairy flavour, moisture content, and mouth coating (Phillips et al. 2010b). Kina roe from the North Island were rated higher in marine, seafood, earthy odours, and higher in the flavours bitter, sour, earthy, herbaceous, seafood, metallic, and astringent mouthfeel, as well as duration and descriptors for after taste – sulphur, metallic and bitter (Phillips et al. 2010b). More detailed studies indicated that most sensory attributes were affected by maturity of the roe, season (autumn, winter, spring, summer), gender, and season by gender interactions (Phillips et al. 2010a). Preece (2006) studied eating quality of farmed Paua (*Haliotis iris*) fed on two diets and also compared farmed and wild-harvest individuals. The study was unable to detect any difference associated with diet or source.

Published research on sensory attributes and eating quality of fish tends to focus on marine-farmed King salmon (*Oncorhynchus tshawytscha*) and how it is harvested and stored (Fletcher et al. 2002, 2003). Aroma, flavour and texture, as well as overall liking for New Zealand King salmon, are all influenced by the way the fish is cooked (microwaved, pan fried, poached, steamed, oven baked, deep fried; Larsen et al. 2011). Trained panels found that the method used to harvest salmon (anesthetisation by CO_2 or AQUI-S®) had a minimal impact on eating quality (Fletcher et al. 2003) and that the eating quality declined according to both the length of storage and technology used to store fish (e.g. storage in modified atmospheres including air, nitrogen and carbon dioxide; Fletcher et al. 2002).

3 CONCLUSION

The enjoyment that arises while experiencing the texture and flavour of food has a primary influence on consumers' decisions to select or re-select a particular product. It is the physical characteristics of these foods that contribute to this enjoyment and the complex emotions that are evoked. When blind tasting products, people quickly conclude whether the food is special or not, and what are the most appropriate situations and places to eat it (e.g. at home alone or when entertaining guests). A number of New Zealand export agri-food sectors tap into these sophisticated consumer perception to establish and enhance the distinctiveness of their foods.

Investment in the collection and use of data on distinctive attributes of New Zealand foods seems to be directly related to the extent that the New Zealand-grown brand is apparent at the point of consumption. For example, research on New Zealand wine and fresh fruit has established which distinctive flavour and texture positions are advantageous over international competitors. However, for meat and seafood (which are mostly public domain foods and usually consumed as part of a meal rather than on their own) there seems to be less information on how the product is distinct in flavour and texture from other competing international suppliers. Such information may only be available in confidential industry reports that have not been accessed as part of this review.

Convenience and the delivery of immediately apparent health and wellness benefits represent food functionality that is dependent on physical characteristics. In this review, we have excluded long-term health benefits associated with certain foods as they require consumers to believe that current consumption will result in future benefit – i.e. credence is important. Food convenience is influenced by the need for preparation and clean-up, messiness during consumption, ease of storage in the home, variety of different uses, suitability for all the family and availability in many shops over the entire year. Different types of fruit are differentiated according to this spectrum of needs for physical properties that enhance convenience.

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