Nothing Else: A Healthier Snack Bar

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Abstract

Diet and nutrition are modifiable risk factors for chronic diseases such as obesity and diabetes. Maintaining blood glucose within homeostatic limits and eating foods that suppress hunger and promote satiety have beneficial impacts on health. In response to the growing consumer demands for healthier foods associated with disease prevention and health promotion, many food manufacturers have reformulated established brand products. However, taste appeal, sustainable ingredients and valid health claims are challenges for successful marketing of healthier food products.

Nothing Else™ is a brand created at the Auckland University of Technology, New Zealand in 2010 with the intention to promote sustainable consumption. Food products of the Nothing Else brand have eight or fewer ingredients, all perceived as natural, that are listed on the front of pack within a circle band displaying the words “Nothing Else”.

The aim of this body of work was to prove the principle that a healthier snack bar under the Nothing Else brand could be developed. The objectives were to produce evidence that the prototype bar would meet the criteria of a nutrient profile required for high-level health claims, and at the same time in comparison with similar commercial bars would have a more favourable effect on blood glucose response and induce similar or better satiety; furthermore, would have favourable effects on snacking habits and glucose homeostasis in the longer term. Alongside these objectives, from a branding and marketing aspect, it was important that the bar would be liked and purchased by the consumer.

In this original body of work, in partnership with a commercial food manufacturer, a healthier snack bar was developed using the nutrient profiling scheme (Food Standards Australia New Zealand) as a guideline. At the time of developing the bar, there were very few snack products available in the New Zealand market that were

made of all natural ingredients, and met nutrient profiling criterion for health claims. The prototype Nothing Else bar contains eight natural ingredients, meets nutrient profiling criterion for health claims, and is able to be manufactured commercially.

The consumer liking study indicated that compared to five top New Zealand brand snacks, the Nothing Else bar was the least liked snack bar. However, after the packaging of the products were presented to the participants, overall liking of the Nothing Else bar increased by 14% ($p = 0.023$), while overall likings for the four commercial products were unchanged. While the most popular commercial bar was ranked the highest for taste and purchase intent, the Nothing Else bar was ranked the highest for healthiness and naturalness. The findings indicated that branding and health related nutrition information could improve consumer liking and brand perception, particularly if backed by marketing.

The snack bar composition and their acute glycaemic and satiety effects were investigated with 26 participants (aged ≥ 50 years). Compared to two top selling commercial snack bars (Bar 1, Bar 2) after consumption of a serving size of each bar on different days, the incremental area under the blood glucose response curve (iAUC) over two hours was 30% lower for the Nothing Else bar than Bar 2 ($p < 0.001$). At 45 minutes after eating, the Nothing Else bar induced the highest fullness rating and lowest hunger rating among the three snack bars. At two hours, fullness induced by the Nothing Else bar was twice that of Bar 2 ($p = 0.019$), but not different to Bar 1 ($p = 0.212$). The Nothing Else snack bar, with its high protein and dietary fibre contents, had a lower glycaemic impact and induced a higher subjective satiety than the two commercial snack bars of equal weight.

The effects of daily consumption of the Nothing Else bar for 6 weeks on snacking habits and glycated haemoglobin (HbA1c) were investigated. During a 13-week trial, twenty-eight participants (aged ≥ 40 years) were randomly allocated to two groups to

either consume the bars as the main snack for 6 weeks (n = 14) or receipt of the bars was delayed for 6 weeks (n = 14) following a stepped wedge design. All participants had HbA1c measured at weeks -1, 0, 4, 6, 10, and 12. A short dietary habits questionnaire was self-completed at weeks 0, 6, and 12. Participants consumed the bars they received instead of other snacks for 6 weeks and found the healthier snack bar was acceptable as part of their daily dietary pattern. Over the 12 weeks, there was a significant reduction in intake of biscuits, cakes and pies (~2 servings/week, $p < 0.05$) in both groups. Fruit juice intake was reduced (~1 serving/week, $p = 0.029$) in the first group. Twenty participants experienced a decrease (n = 15) or no change (n = 5) in HbA1c (range 0-4 mmol/mol); while eight participants experienced an increase in HbA1c (range 0.5-2.5 mmol/mol). There was high compliance with the healthier snack intervention and a trend toward a favourable effect on glucose homeostasis. The results suggested that habitual snacking behaviour has the potential to be improved through changes in the food supply and in the longer term may reduce the impact of poor nutrition on public health.

This body of work was proof of concept for the feasibility of development of a commercial healthier food product by a university in partnership with the food industry. The translation of the diverse skills, such as health and nutrition; food science; marketing; creative commination, was one small step towards providing a food environment that is supportive of a healthier diet.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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Mary Yan

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Abbreviations

AICR	America Institute for Cancer Research
AUT	Auckland University of Technology
BMI	Body mass index
CHO	Carbohydrate
CVD	Cardiovascular disease
FAO	Food and Agriculture Organisation of the United Nations
FSANZ	Food Standards Australia New Zealand
GI	Glycaemic index
GL	Glycaemic load
Gr	Glycaemic response
HbA1c	Haemoglobin A1c
iAUC	Incremental area under the curve
Kj	Kilojoule
MBIE	Ministry of Business, Innovation and Employment
MOH	Ministry of Health New Zealand
NCDs	Non-communicable diseases
NE	Nothing Else
NPS	Nutrient profiling score
NSP	Non-starch polysaccharide
OECD	The Organisation for Economic Cooperation and Development
PUFA	Polyunsaturated fatty acid
RS	Resistant starch
SFA	Saturated fatty acid
T2DM	Type 2 diabetes mellitus
WCRF	World Cancer Research Fund
WHO	World Health Organisation

List of Publications

This thesis is based on the work contained in the following papers referred to in the text:

Paper I Yan, M. R, Brown, D., Parsons, A., Whalley, G. A, Hamid, N., Kantono, K., Donaldson, B., & Rush, E. (2015). Branding, ingredients and nutrition information: consumer liking of a healthier snack. *Journal of Food Research*; 4:64-72. doi:10.5539/jfr.v4n5p64 (Chapter 4)
(Yan 80%, Rush 12%, Brown, Parsons, Whalley, Hamid, Kantono, and Donaldson 8%)

Paper II Yan, M. R., Parsons, A., Whalley, G. A., Kelleher, J., & Rush, E. (In press). Snack bar composition and their acute glycaemic and satiety effects. *Asia Pacific Journal of Clinical Nutrition*; 26(4). doi:10.6133/apjcn.072016.04 (Chapter 5)
(Yan 80%, Rush 14%, Parsons, Whalley, and Kelleher 6%)

Paper III Yan, M. R., Parsons, A., Whalley, G. A., & Rush, E. (2017). Effects of a healthier snack on snacking habits and glycated Hb (HbA1c): a 6-week intervention study. *British Journal of Nutrition*. doi:10.1017/S000711451 6004372 (Chapter 6)
(Yan 80%, Rush 16%, Parsons and Whalley 4%)

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Thanks to all the participants, for your time and enthusiasm for the research. The findings obtained from the experimental trials (consumer liking, glycaemic and satiety responses, and intervention) helped the research be more realistic and increased the understanding of what people say may be different to what they do.

Finally, my sincere appreciation and thanks to my parents for your understanding and support.

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Ethical approvals were obtained from AUT Ethics Committee (Appendix B): ethics application No.13/184, approved on November 19, 2013; ethics application No.14/342, approved on November 25, 2014; ethics application No.14/379, approved on December 17, 2014.

Chapter 1

Introduction

Dietary exposure over a life time contributes greatly to the risk of chronic diseases (World Health Organisation, 2003). The increased prevalence of obesity and type 2 diabetes mellitus (T2DM) in both developed and developing countries is associated with changes in the food supply and lifestyle. In particular, energy intake and physical activity play critical roles in the management, treatment, and prevention of T2DM and its related phenomenon, obesity (Hurt, Frazier, McClave, & Kaplan, 2011). The increasing demand from consumers and health organisations for healthy, high quality foods associated with disease prevention and health promotion is a challenge for the food industry. With an increasing preference for healthy diets, the development of new food products with nutrition and verifiable health claims will make it easier for consumers to exercise healthy choices (Combris, Goglia, Henini, Soler, & Spiteri, 2011; Food Standards Australia New Zealand, 2015).

There is clear evidence that keeping blood glucose stable (Brand-Miller, Hayne, Petocz, & Colagiuri, 2003; Reynolds, Stockmann, Atkinson, Denyer, & Brand-Miller, 2009; Solomon et al., 2010), and eating foods that suppress hunger and promote satiety (Bell & Rolls, 2001; Wilde, 2009) have beneficial impacts on health and prevention of non-communicable diseases (NCDs) including cardiovascular disease, obesity, T2DM, and some cancers. In the last 20 years, food reformulation research has been focused on the reduction of the glycaemic index and glycaemic load of foods, and the regulation of hunger and satiety. In particular, the development of healthier cereal-based products is desirable because cereals contribute 50% of the dietary energy of the planet (World Health Organisation, 2003). Dietary inclusion of wholegrain cereals is known to protect

against NCDs (Fardet, 2010; Parker et al., 2013; Sarwar, Sarwar, Sarwar, Qadri, & Moghal, 2013).

This chapter outlines the background of the problem to be informed by research and defines the importance of the development of healthier foods, in particular, a nutrient dense cereal-based snack bar that is the focus of this research. Gaps in the body of knowledge are explored. The Nothing Else brand is briefly introduced. The direction of the thesis is presented, and finally the framework of the thesis is outlined chapter-by-chapter.

Background of the problem to be addressed

Non-communicable diseases are the leading causes of disability and premature death worldwide, contributing to over 68% of all deaths during 2012 (World Health Organisation, 2014a). The prevalence of NCDs continues to increase globally. Obesity and T2DM are reaching epidemic proportions worldwide and affecting more than 50% of the adult population (Bauer, Briss, Goodman, & Bowman, 2014) and now are showing worrying trends by starting in early life. The cost of treatment and healthcare for the adverse health effects is large and growing. Rapid changes in the environment and eating behaviours, and physical inactivity have been suggested as likely causes (Bauer et al., 2014). However, NCDs are largely preventable and there is strong evidence that alterations in dietary patterns have positive impact on health throughout life course (World Health Organisation, 2003, 2014a).

In New Zealand, NCDs accounted for 89% of all deaths in 2014 (World Health Organisation, 2014b). The New Zealand health survey (Ministry of Health NZ, 2014) showed that 31% of New Zealanders aged ≥ 15 years were obese, a further 35% of adults were overweight, and more than 240,000 had diagnosed T2DM. This level of prevalence places a huge current and future burden on New Zealand health services.

Furthermore, NCDs are intergenerational (Godfrey, Gluckman, & Hanson, 2010), which suggests that improvement in diet will affect future generation also. The improvement of food supply and health is currently a direction of the New Zealand Ministry of Business, Innovation and Employment. The government is looking at ways to link food production in New Zealand with leveraging of high value nutrition products that have evidence to allow health claims. In respect of the food industry, a wider availability of food with nutrition and verifiable health claims could increase retail sales and help consumers to make healthier choices. Therefore, working with the food industry to produce healthier products is a social priority as part of the prevention of NCDs (Food Standards Australia New Zealand [FSANZ], 2015).

Rational and significance of the study

Snack food, food eaten outside main meals, contributes more than 20% of the daily energy intake of the population (Bilman, van Trijp, & Renes, 2010; Furchner-Evanson, Petrisko, Howarth, Nemoseck, & Kern, 2010). Snack bars are a popular snack, particularly for purchase from vending machines and cafes, and for inclusion in packed lunches to be eaten at school and at work. In 2014, the sales value of snack bars in New Zealand was NZ $132 million with oat-based (muesli) bars accounting for NZ $71 million, forecast to retain the same sales value by 2019 (Euromonitor International, 2015). Muesli bars are regarded by many as being healthy, however, most of muesli bars are high in added sugar and fat: energy dense and low in protein, fruits, and dietary fibre (personal survey of supermarket packaged snack bars). In New Zealand, 55% of the packaged food, which includes snack bars, has been reported as unhealthy based on nutrient profiling criterion (Ni Mhurchu et al., 2016).

To date, snacking behaviour and the impact of snacking on health (Bilman et al., 2010; Hess, Jonnalagadda, & Slavin, 2016) are largely unknown. Snack foods are

usually categorised based on the eating situations, rather than the health properties of foods, such as glycaemic impact and satiety (Bilman et al., 2010; Williams, Noakes, Keogh, Foster, & Clifton, 2006). On examination of snack products on sale before this work was undertaken, there were very few snack products that would meet the nutrient profiling criterion for health claims. In addition, there were very few studies available on snack composition in relation to relevance of satiety-related consumer objectives.

As well as the nutrients in a food, a huge part of what influences a retail consumer is marketing and advertising. One aspect of marketing and advertising is the packaging of the product and the labelling (Ailawadi & Keller, 2004; van Herpen & Trijp, 2011).

Hence, gaps in the body of knowledge that the proposed body of work initially sought to fill are understanding the influences of labelling on either actual consumption or potential compensatory eating behaviour; the relative effects of branding, labelling and price; verifiable high-level heath claims for food products; and the effects of snacks on glycaemia, satiety and snacking habits.

The Nothing Else brand

Nothing Else, a food brand trademark now owned by the Auckland University of Technology, New Zealand, was an innovative and dominant front-of-pack food label that lists all ingredients in the packaged product (D. Brown, 2010). The concept behind this approach is to allow customers to have easy access to ingredients of products that they purchase. The snack foods under the Nothing Else brand are made with natural and familiar ingredients, eight or less in total. There are no additives, no preservatives and nothing artificial. The Nothing Else label is a circle band displaying the words ‘Nothing Else’, with a list of ingredients being placed inside the band (Figure 1).

Figure 1. Nothing Else label, a list of ingredients is placed inside the band (used with permission from D. Brown).

Direction of the thesis

The overarching research question examined in this thesis was: Can a healthier snack bar be formulated that meets the Nothing Else brand criteria, meets the criteria for nutrition and health claims in New Zealand, and be accepted by consumers as part of their regular diet? In addition, can it be developed and produced in partnership with a commercial food manufacturer? The health criteria sought to be satisfied would focus on lowering the glycaemic impact, prolonging satiety, improving habitual snacking behaviour and reducing the impact of poor nutrition on public health in the longer term.

Thesis outline

This thesis comprises seven chapters (Figure 2). Chapter one provides a general introduction to the research topic and a rationale and significance for the study together with the research problem and gaps in the body of knowledge. Chapter two reviews the current literature in relation to the prevalence and causes of chronic diseases, in particular obesity and T2DM. Chapter three presents the experimental approach and the development of the Nothing Else snack bar. Chapters four, five, and six are the experimental studies including consumer study, glycaemic and satiety effects, and intervention study that are adapted from peer-reviewed journal articles arising from this thesis. Chapter seven comprises an overall discussion and conclusions, and recommendations. The appendices comprise relevant materials including participant information sheets, informed consent forms, and ethical approval forms.

Thesis Flow Chart

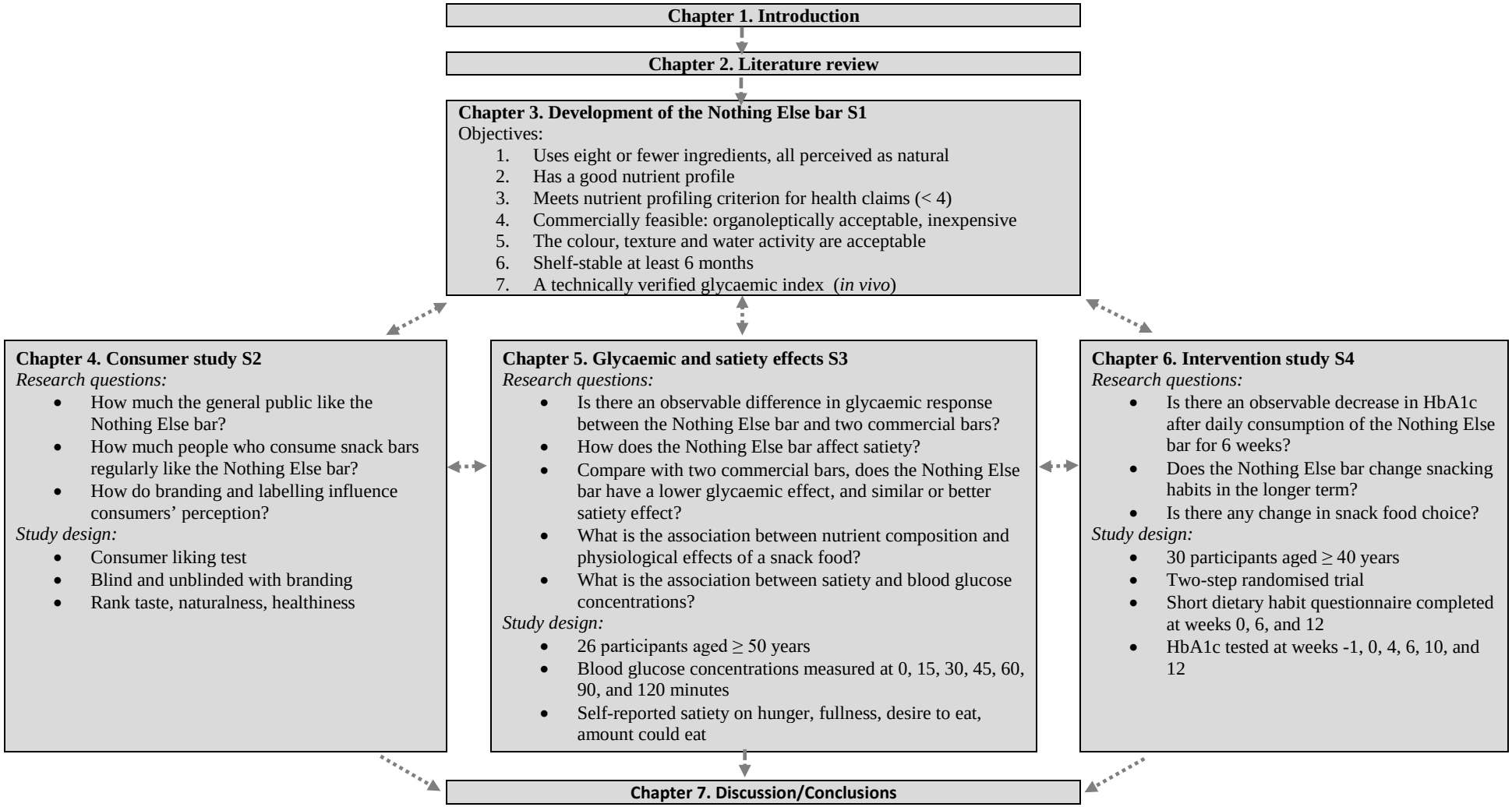


Figure 2. Overview of the thematic chapters of the thesis

Chapter 2

Literature Review

The prevalence of chronic diseases is increasing worldwide. Obesity and diabetes[1], two of the major chronic health issues, place a huge burden on the health services globally. Rapid changes in environmental and dietary behaviours, and physical inactivity have been suggested as likely causes (Bauer et al., 2014). There is strong evidence that nutrition is a modifiable factor in relation to the risk of chronic diseases (World Health Organisation, 2003). It is therefore a social priority to support and work with the food industry to produce a wider range of healthier foods to meet the increasing demand of consumers wanting healthier foods.

In this literature review, the burden of chronic diseases is discussed in order to define the problem. The causes associated with the increase in prevalence of chronic diseases are reviewed. The current knowledge on the health impact of glycaemic index and glycaemic load of foods, and also the food properties which affect satiety and energy intake are reviewed. In respect to the development of healthier foods, the nutritional and health aspects of macronutrient substitutions are also discussed.

Literature was sourced from the AUT library health databases including web of science, Scopus, EBSCO health, and Google scholar. Literature was searched across disciplines and types of literature including academic papers, peer-reviewed journal articles, and policy literature. The literature search was constructed for food, obesity, diabetes, reformulation, health and nutrition. Most of the literature, where possible, was published within 10 years prior to the completion of this study, nominally August 2016.

[1] Diabetes mellitus is the correct term, but diabetes is in common use.

The burden of chronic diseases

Chronic diseases, such as cardiovascular disease (CVD), obesity, diabetes, stroke, and some types of cancer, are the primary cause of the mortality in the world, representing 68% of the 56 million total deaths in 2012 according to the World Health Organisation (2014a). Over the past few decades, there have been rapid changes in food supply and lifestyle as the result of industrialisation, rapid urbanisation and market globalisation (World Health Organisation, 2003). The prevalence of chronic diseases has, and continues to, increase at a significant rate. It has been projected that by 2030, the annual deaths caused by chronic diseases will increase by 27% globally (World Health Organisation, 2014a).

Diabetes describes a group of chronic metabolic diseases in which a person experiences a higher than normal blood glucose concentration. Type 2 diabetes, the most common type of diabetes, results from insulin resistance, a condition in which cells fail to use insulin normally, sometimes combined with an absolute insulin deficiency (World Health Organisation, 2006). The prevalence of T2DM has reached epidemic proportions in both developed and developing countries. In 2014, there were 422 million people aged ≥ 18 years worldwide with diabetes, with T2DM making up 90% of all cases (World Health Organisation, 2016). The prevalence of diabetes is set to rise even further, by 2030 the number is estimated to reach 550 million, a 53% increase (Whiting, Guariguata, Weil, & Shaw, 2011). Further, high blood glucose concentration, defined as a distribution of fasting plasma glucose in a population that is higher than the theoretical distribution that would minimise risks to health (World Health Organisation, 2016), caused 3.7 million deaths worldwide in 2012, of which 43% were persons younger than 70 years (World Health Organisation, 2016).

In New Zealand, more than 240,000 people have been diagnosed with diabetes and it is thought another 100,000 New Zealanders have diabetes but are unaware of

their condition (Ministry of Health NZ, 2014, 2015). Type 2 diabetes usually develops in adults, particularly in those who are overweight or obese. However, it is now increasingly being diagnosed in teenagers and children, and is clearly associated with obesity (Ministry of Health NZ, 2014). The cost of treatment and healthcare for the adverse health effects of diabetes is large and growing.

Obesity is an independent risk factor associated with chronic diseases such as T2DM, hypertension, and CVD (World Health Organisation, 2003). In 2014, 31% of the New Zealanders aged ≥ 15 years were obese, a further 35% of adults were overweight (Ministry of Health NZ, 2014). The prevalence of obesity is positively and strongly related to the prevalence of a variety of chronic diseases, in particular T2DM, and it is reasoned that weight loss would be associated with reduction in the prevalence of chronic diseases. Given that excess energy intake results in body weight gain, food plays an important role in body weight management, and potentially in the development of T2DM.

Clinical characteristics of the epidemic in general populations

The prevalence of obesity and T2DM varies among countries and regions. The increase in T2DM in Asian countries is faster and the pattern differs from that in the Western world. In Asian populations, for instance, the diseases have developed more rapidly and occur more frequently in younger age groups, as well as in people with much lower body mass index (BMI) (Lee, Brancati, & Yeh, 2011; Ramachandran, Snehalatha, Shetty, & Nanditha, 2012).

Most Asian people with diabetes are aged between 45 to 64 years, whereas T2DM mainly affects Caucasians who are older than 65 years (Rhee, 2015). Asian people for the same age, gender, and BMI have a higher proportion of body fat, particularly abdominal than European populations and are more insulin resistant than Europeans

(Rhee, 2015). As a consequence Asian people, particularly South Asians, are at a higher risk of chronic diseases including T2DM compared with Europeans (Lee et al., 2011; Ramachandran et al., 2012). It has also been reported that early dysfunction in insulin secretion predisposes Asian people to T2DM in various populations (Rattarasarn, Soonthornpan, Leelawattana, & Setasuban, 2006; Rhee, 2015).

The prevalence of obesity and T2DM varies among different Asian countries, and among different locations in the same countries. The prevalence of obesity and diabetes is more pronounced in India and Bangladesh than in other countries (Boffetta et al., 2011). For all the characteristics of the epidemic in Asia, environmental factors such as urbanisation, as well as genetic influences have a vital impact (Ramachandran et al., 2012).

Causes of the rise in prevalence of obesity and type 2 diabetes

Environmental factors

During the last three decades, the human social environment has become a key contributor to the prevalence of the epidemic of obesity and T2DM (Marti, Martinez-Gonzalez, & Martinez, 2008; Romao & Roth, 2008). The growth of diet-related chronic diseases has been related to the rapid change in lifestyle, driven by the increasing rate of industrialisation, urbanisation, and market globalisation (World Health Organisation, 2003). Even though economic development has improved the nutrition and healthcare conditions, it has also led to the rapid increase in prevalence of obesity, diabetes and heart disease. Increased availability of food, especially energy dense foods (e.g. high intakes of animal source foods, dairy, and sugar-added food), and low energy expenditure, have significant negative consequences and predisposed people to obesity and T2DM (Pakseresht et al., 2014; Popkin, 2009).

Social and cultural changes may also contribute to the increase in prevalence of T2DM, for instance, migration. Research in a metropolitan city in India has shown that migration from rural areas to cities commonly leads to obesity, glucose intolerance, and dyslipidaemia (Misra et al., 2001; Misra & Shrivastava, 2013). Dyslipidaemia, a recognised cardiovascular risk factor, is an abnormal amount of lipid (e.g. cholesterol or fat) in the blood, and is often due to diet and lifestyle. Epidemiological studies of diabetes have revealed that migrant populations, typically people originally from developing counties, have a higher prevalence of T2DM than the host populations (Mohan, Sandeep, Deepa, Shah, & Varghese, 2007).

Fast food[2] and sedentary behaviour

Changes in food supply and demand have altered dietary patterns. Fast foods, that are rich in fat and salt, are readily available in numerous food outlets. Fast food consumption is highly related to higher energy intake and poor nutrition. Eating fast food more than twice a week is associated with an increased risk of weight gain to the point of obesity (World Cancer Research Fund & America Institute for Cancer Research, 2007). Excess fast food consumption is related to the increasing prevalence of CVD and T2DM (Bahadoran, Mirmiran, & Azizi, 2015), particularly in developing countries (Mohan, Sudha, et al., 2007).

In addition, rapid economic transition in many developing countries including Asian countries has resulted in changes in occupations, especially occupations with reduced physical activity (Ramachandran et al., 2012). A huge proportion of the agriculture labour population has shifted to sedentary occupations that are less physical demanding (Mohan, Sandeep, et al., 2007). Moreover, the physical activity patterns of children and youth have become more sedentary due to access to the internet, computer

[2] Fast food is the term given to food that can be prepared and served very quickly, typically the term referred to food sold in a store and served in a packaged form for immediate consumption elsewhere.

games, televised entertainment and motorised transportation. The changes in lifestyle have contributed to an overall decline in time, intensity and frequency of physical activities (Mohan, Sandeep, et al., 2007; Ramachandran et al., 2012). All these factors help explain the increased risk of obesity in both childhood and adulthood (Utter, Scragg, & Schaaf, 2006; Utter, Scragg, Schaaf, & Fitzgerald, 2006; World Cancer Research Fund & America Institute for Cancer Research, 2007).

Lifecourse health and genetic predisposition

Body mass index (BMI, kg m^{-2}) is a simple anthropometric measurement of body weight status in relation to height, and is commonly used to quantify health risk associated with body fatness (BF) (World Health Organisation, 2004). However, the associations between BMI and and the accumulation of BF, and associated health-risk profiles have been shown to vary with age, ethnicity, due to differing physiological responses to fat storage between ethnic groups (Stommel & Schoenborn, 2010). The risk profile is intergenerational and related to both the genetic profile of an individual (fixed) and how the genes are expressed (epigenetics), in particular the intrautero environment and early life course events have a profound effect on later health (Gluckman, Hanson, Cooper, & Thornburg, 2008).

It is now generally accepted that Asian populations have an increased risk of developing gestational diabetes (Tutino et al., 2014), T2DM and related metabolic abnormalities, compared to other ethnic groups (Misra & Shrivastava, 2013; Mohan, Sudha, et al., 2007). Despite the lower prevalence of obesity as defined by BMI, people of Asian origin have a greater waist-to-hip ratio and more intraabdominal fat that is associated with greater risk of CVD and T2DM than European populations (Misra & Shrivastava, 2013). Accordingly, a revised threshold of 25 kg m^{-2} has been recommended by the World Health Organisation as obese for Asian populations (Gatineau & Mathrani, 2011), as opposed to 30 kg m^{-2} for European populations.

In addition, the glycaemic load of the Asian diet which includes large amount of white rice is higher than that of European diet (Boers, Seijen Ten Hoorn, & Mela, 2015). Also people who are more deprived tend to consume more refined carbohydrate foods which increase the glycaemic load. Therefore, from a public health point of view, changes in the food supply, an example is snacks, should be targeted at populations that would benefit the most from healthier food choices.

In summary, obesity is a consequence of excess energy intake, in which food plays a crucial role. Making good dietary and lifestyle choices are therefore very important across the life course for prevention of body weight gain and obesity, which in turn leads to improvement in health and prevention of chronic diseases (World Health Organisation, 2003). There is evidence that the size (the weight and volume of food) and energy density (kJ g^{-1}) of food determine the feeling of fullness and subsequent food intake, when equal energy diets are ingested (Bolhuis, Lakemond, de Wijk, Luning, & de Graaf, 2013; Ello-Martin, Ledikwe, & Rolls, 2005). In recent decades, the reduction of the glycaemic index and glycaemic load of foods and the regulation of hunger and satiety have been the two major objectives for food reformulation research. The glycaemic index, glycaemic load and satiety are discussed in the following sections.

Glycaemic index and glycaemic load

The glycaemic index (GI) is a measure of the blood glucose level increase after carbohydrate consumption (D. J. Jenkins et al., 1981). The concept of GI was initially developed by Jenkins et al. in the early 1980s while studying the physiological effect of foods on blood glucose response to treat diabetes. The GI is defined as the incremental area under the two-hour blood glucose response curve (iAUC), following a 12-hour fast period, elicited by a 50 g available carbohydrates portion of a food, expressed as a

percentage of the response after consuming 50 g of anhydrous glucose[3] by the same subject on a different day (International Organisation for Standardisation, 2010; Wolever, 2006).

The glycaemic load (GL) is a more recent application of the GI measure which is used to assess the impact of carbohydrates consumption while taking into account the amount of carbohydrates that is consumed. The GL is defined as the GI of a food times the amount of carbohydrate consumed in grams divided by 100 (Glycaemic Research Institute, 2008). Therefore, the GL combines both the quality (GI value) and the quantity (g) of the carbohydrates consumed.

The GI ranks food on a scale from 0 to more than 100 according to its relative effect on blood glucose concentration compared to the same carbohydrate load of glucose. By definition the GI of glucose is 100. The GI of food is classified as high (≥ 70), medium (56-69), and low (≤ 55) (Brand-Miller, Foster-Powell, & Colagiuri, 2002). A low GI food releases glucose gradually and leads to relatively low postprandial blood glucose concentration, whereas a high GI food causes a rapid and/or a more prolonged rise in postprandial blood glucose concentration over two hours. In the past few decades, with growing interest in the GI, the GI and GL values of more than 2,480 individual foods have been tested by many studies and compiled into tables (Atkinson, Foster-Powell, & Brand-Miller, 2008; Brand-Miller & Foster-Powell, 2011; Foster-Powell, Holt, & Brand-Miller, 2002). These tables are commonly used in research and clinical practice in relation to health. For example, as a staple carbohydrate food, more than 200 different types and brands of bread have been tested.

[3] Originally either glucose or white bread was used as reference food, however, white bread is no longer recommended inasmuch as its composition varies worldwide.

Glycaemic response and the glycaemic index of foods

Glycaemic response is not the same as glycaemic index. Glycaemic index is expressed as a single number. Glycaemic response is a measure of the dynamic changes of blood glucose after consumption of a whole food. There are a variety of situations which influence glycaemic response of a food: the type of carbohydrate (available or unavailable), physical entrapment of the carbohydrate molecules within the food, other ingredients such as fat and protein, and physiological differences in test subjects including insulin production and resistance (Wolever, 2006). Studies of nutrition and food sciences in this field have identified a range of food and structure-related factors which affect the GI and glycaemic response of foods (Norden, 2005). These factors are discussed in this section.

Food that do not contain carbohydrate, such as steak or eggs, cannot have the GI measured (Wolever, 2006). Theoretically, the GI of a multi-component food product or meal can be calculated from the carbohydrate portions and the GI values of individual ingredients, such that low GI ingredients will reduce the GI of the food product or meal. For example, adding fat and/or soluble dietary fibre to food will reduce and delay the glycaemic response by slowing the gastric emptying rate. The hypothesis is discussed further below.

Effect of dietary fibre

The term ‘available carbohydrates’ refers to carbohydrates which are absorbed in the small intestine and metabolised in the body via pathways which can, at least potentially, yield glucose. In contrast, carbohydrate components of foods that are not digested in the small intestine are referred to as ‘unavailable’ non-glycaemic carbohydrates or dietary fibre (Wolever, 2006; World Health Organisation, 1998). The definition of dietary fibre in relation to health claims is debated as dietary fibre can be

derived from both natural and synthetic sources (Mann & Cummings, 2009). Plant (natural) dietary fibre comprises cellulose, hemicellulose, pectins, resistant starch (RS), and other non-starch polysaccharide (NSP). Undigested dietary fibre reaches the large intestine and is fermented by colonic microflora with end-products of short-chain fatty acids (SCFA), carbon dioxide, hydrogen and biomass (Food and Agriculture Organisation of the United Nations, 2002).

Epidemiological studies have confirmed that dietary fibre in diet reduces the risk of CVD (Estruch et al., 2009) and T2DM (Dodevska et al., 2016; Krishnan et al., 2007). Furthermore, evidence from experimental studies has also suggested that dietary fibre improves impaired glucose tolerance, blood glucose and insulin concentrations in people with T2DM (Steyn et al., 2007; World Health Organisation, 2003). Dietary fibre intake is inversely associated with body weight and body fat, as a result of improved satiation, reduced absorption of other nutrients, and modified secretion of insulin (Slavin, 2005).

Cellulose, chitin, β-glucans, gums, oligofructose, pectins, fructoligosaccharides, and RS are forms of functional fibre, because while they do not contribute to calories, they play other roles in body maintenance. During food manufacturing processes, dietary fibre can be added to foods as ingredients. The gel-forming property of dietary fibre slows down the rate of absorption of metabolically available carbohydrates and consequently reduces blood glucose and insulin responses, and improves gut health including laxation.

Effect of the nature of starch

Starch is composed of broadly two types of glucose polymers: the linear amylose and the branched amylopectin. Most food starches contain 70-80% of amylopectin by weight, with the remainder amylose (W. H. Brown & Poon, 2005). Due to their

structural differences, their natures also differ. It has been reported that amylose is more resistant to hydrolytic enzyme activity than amylopectin (Topping et al., 1997). High-amylose starch, for example maize starch containing 50-70% of amylose, is resistant to the hydrolytic conversion of starch to sugars, and is therefore used commercially as an ingredient to raise the resistant starch content of food (I. Brown, Conway, & Topping, 2000). Åkerberg, Liljeberg, and Björck (1998) reported that the GI of bread was reduced with increased amylose content.

Effect of sugars

Although sugar (oligo, di and monosaccharides) may be digested and absorbed more rapidly than starches, the sugar content of a food does not necessarily relate to the GI value (D. J. Jenkins et al., 1981; Wolever, 2006). For example, fructose and galactose require metabolic transformation to glucose in the liver, this slow transformation subsequently has a very small effect on blood glucose and the glycaemic response (Coss-Bu, Sunehag, & Haymond, 2009; Norden, 2005). Fructose has a very low GI of 19 compared to glucose (100), sucrose (65), and lactose (46) (Foster-Powell et al., 2002). So fructose is often recommended for people with diabetes. Moreover, fructose is much sweeter than sucrose and glucose by weight, so less is needed to provide a required sweetness level.

Effect of fat

Adding fat, such as oils, to a carbohydrate food reduces its GI by delaying gastric emptying and affecting insulin secretion (Al Dhaheri et al., 2015; Marathe, Rayner, Jones, & Horowitz, 2013). However, while adding fat reduces the initial rise of blood glucose after eating, it may be associated with a prolonged and elevated blood glucose concentration and a second peak in glucose response (Owen & Wolever, 2003). In addition, fat is energy dense and some fats such as saturated and trans fatty acids have

been associated with higher risk of CVD, impaired glucose tolerance, and T2DM (Food and Agriculture Organisation of the United Nations, 2010).

Effect of protein

It is generally thought that protein is negatively correlated with GI by delaying gastric emptying. Study results have been varied depended on the different types of proteins and amino acids (Wolever, 2006). A mixture of milk and soy protein has been found to have a marked effect on reducing glucose response yet insulin secretion is increased (Ang, Muller, Wagenlehner, Pilatz, & Linn, 2012; McGregor & Poppitt, 2013), whereas lean beef was found to have no effect on glucose and insulin responses (Turner, Keogh, & Clifton, 2016; Westphal, Gannon, & Nuttall, 1990). In addition, some studies have shown that milk proteins have insulinotropic properties, consequently increasing postprandial insulin levels (McGregor & Poppitt, 2013; Nilsson, Stenberg, Frid, Holst, & Bjorck, 2004).

Glycaemic index, nutrient profiles and health

Over the past thirty years, there have been a large number of studies undertaken to investigate the relationship between GI, GL and health. Whilst the results have been inconsistent, there is little evidence that low GI, low GL diets have a negative health impact. Rather the opposite is true.

Epidemiological studies on glycaemic index and chronic diseases

Epidemiological studies on the protective effects of low GI and GL diets against chronic diseases have shown a reduction in risk factors, such as triglycerides (TG), total high density lipoprotein (HDL) and low density lipoprotein (LDL) cholesterol, insulin levels and insulin sensitivity (Ebbeling et al., 2005; Liljeberg & Bjorck, 2000).

The GI concept was initially developed to help glycaemic control of people with diabetes. Research in this field has indicated positive effects of low GI diets on medium-term glycaemic control as assessed by haemoglobin A1c (HbA1c) (Brand-Miller et al., 2003; D. J. Jenkins et al., 1983; Yusof et al., 2009). Insulin sensitivity was improved after adoption of low GI diets (McMillan-Price & Brand-Miller, 2006; Roberts & Liu, 2009). Willett, Manson, and Liu (2002) reported that in more than 40,000 men the low GI, low GL diets halved the relative risk of developing T2DM. Compared with those following high cereal fibre, low GI diets, people with low cereal fibre, high GL diets had an increased risk of T2DM (Hu et al., 2001; Willett et al., 2002). Moreover, cross-sectional studies showed that the higher the GI of a person's diet, the worse the glycaemic control for people with type 1 or type 2 diabetes (Wolever, 2006).

Despite van Dam, Visscher, Feskens, Verhoef, and Kromhout (2000) reporting that there was no association between GI and CVD, a 10-year follow-up Nurses Survey Study indicated that a high GL diet was closely related to the increased risk of CVD (Liu et al., 2000). It has also been shown there were negative correlations between HDL cholesterol with GI as well as with GL (Slyper, Jurva, Pleuss, Hoffmann, & Gutterman, 2005). In addition, a 18-year follow-up Nurses Survey Study showed that high GL was positively associated with incidence of strokes, especially among those who were overweight or obese (Oh et al., 2005).

Intervention studies on glycaemic index and health

Non-communicable diseases are largely preventable through lifestyle intervention. While genetic predisposition is non-modifiable, other risk factors such as environmental and cultural factors, physical inactivity, dietary patterns, and weight are positively modifiable. A low GI diet has the potential to reduce metabolic risk factors including postprandial hyperglycaemia, insulin resistance, dyslipidemia, endothelial dysfunction,

and impaired haemostasis (Burton, Monro, Alvarez, & Gallagher, 2011). Whole grains foods have lower GI values than their refined equivalent. The accumulated evidence supports public health recommendations to replace refined grains with whole grains to reduce the risk of developing T2DM (Aune, Norat, Romundstad, & Vatten, 2013).

Low GI foods have also been shown to increase satiety and reduce food intake, and subsequently the risk of obesity, due to a slower blood glucose uptake and insulin response (Blaak et al., 2012), and the absence of reactive hyperglycaemia (Brand-Miller et al., 2002).

Bjorck and Elmstahl (2003), and Ostman, Frid, Groop, and Bjorck (2006) reported an improvement of insulin sensitivity in women at risk of T2DM after replacing common bread with a low GI high cereal fibre bread. The beneficial effects of low GI diets have also included improved blood glucose control, lowered HbA1c and improved glucose tolerance and insulin sensitivity (Brand-Miller et al., 2003; Reynolds et al., 2009; Solomon et al., 2010).

Many studies indicated that the regulation of hunger and satiety would have beneficial impact on health, for example, an increased satiety reduces food intake resulting in improvement in weight management (Norden, 2009). Therefore, the development of food products that result in improved satiety is one objective in respect to healthier food reformulation.

Hunger, satiation and satiety

Hunger is the biological need that drives the search for food. The feeling of hunger determines when, what, and how much to eat. Satiation, also called intra-meal satiety, is the feeling of fullness during the meal that prompts the termination of eating. Satiety is the feeling of fullness between meals that persists after eating and inhibits a new intake (Gerstein, Woodward-Lopez, Evans, Kelsey, & Drewnowski, 2004).

During the course of eating, the sensation of fullness develops, hunger reduces, the desire to eat reduces and satiation occurs. The physiological changes that occur prevent further consumption. After food been ingested, satiety develops. The state of satiety regulates the inter-meal period of fasting and thus is likely to lead to a reduction in food consumption at the next meal (Gerstein et al., 2004). Thus, both satiation and satiety are important for controlling energy intake.

Energy content, individual macronutrients and the physical properties of foods affect satiety in various ways. Each of these factors is reviewed in this section.

Energy density and satiety

Energy density (kJ g^{-1}) of foods is defined as the amount of available energy for a given mass of food. The energy density of food has been shown to be positively associated with energy intake, obesity, and elevated fasting insulin levels (Aburto, Cantoral, Hernandez-Barrera, Carriquiry, & Rivera, 2015; Mendoza, Drewnowski, & Christakis, 2007). The macronutrients of foods, including carbohydrates, fat, protein, dietary fibre, and water, affect energy density. Fat has a higher energy density that is twice of that of carbohydrates and protein (37.6 kJ g^{-1} vs. 16.7 kJ g^{-1}). Dietary fibre and water have very low energy density values.

Studies have shown that in the short term, low energy density foods such as fruits and vegetables increase satiety, decrease feelings of hunger and reduce energy intake. Bell and Rolls (2001) found that compared with the high energy density meal (7.32 kJ g^{-1}) group, the energy intake of the group with a low energy density meal (5.23 kJ g^{-1}) was 20% lower, though the meals had the same volume for both groups. In the long term, low energy density foods have been shown to promote weight reduction (Papagiannidou, Tsipis, Athanassiadou, Petrou, & Athanassiadou, 2013). The result of a multi-ethnic cohort study involving 191,000 subjects indicated that one unit increase in

energy density was associated with approximately one unit increase in BMI, irrespective of ethnicity or gender (Howarth, Murphy, Wilkens, Hankin, & Kolonel, 2006).

Macronutrients and satiety

The influence of food macronutrients on appetite regulation and weight management is not clearly understood, in spite of a large number of studies on this topic carried out over the last few decades (Crino, Sacks, Vandevijvere, Swinburn, & Neal, 2015; Gerstein et al., 2004). Some studies have reported no differences found in the satiation value of dietary macronutrients (Barkeling, Rossner, & Bjorvell, 1990; Poppitt & Prentice, 1996; Rolls et al., 1991). However, more recent evidence suggests that dietary protein is a more satiating macronutrient compared with fat and carbohydrate (Anderson & Moore, 2004; Astrup, 2005; Chambers, McCrickerd, & Yeomans, 2015; Paddon-Jones et al., 2008; Pesta & Samuel, 2014). Carbohydrates have an intermediate satiation value, while fat has the lowest satiation value (Chambers et al., 2015; Paddon-Jones et al., 2008).

Effect of carbohydrates on satiety

The effect of carbohydrates on satiety is likely caused by changes in blood glucose concentration in the short term (Anderson & Woodend, 2003; Niwano et al., 2009). Studies have suggested that when blood glucose concentration falls, appetite increases (Brand-Miller et al., 2002; Ludwig, 2003). Low GI foods release glucose gradually and lead to a relatively stable postprandial blood glucose concentration (Figure 3), would not trigger the same intensity of feelings of hunger. Thus, low GI food is considered more satietogenic than high GI food (Bornet, Jardy-Gennetier, Jacquet, & Stowell, 2007).

As would be expected, starch in its natural semicrystalline state is resistant to digestion. The semicrystalline structure of starch slows the rate of digestion; with an intact structure having greater effect on reduction of GI compared to a gelatinised structure achieved from cooking (Mishra, Hardacre, & Monro, 2012; Norden, 2005).

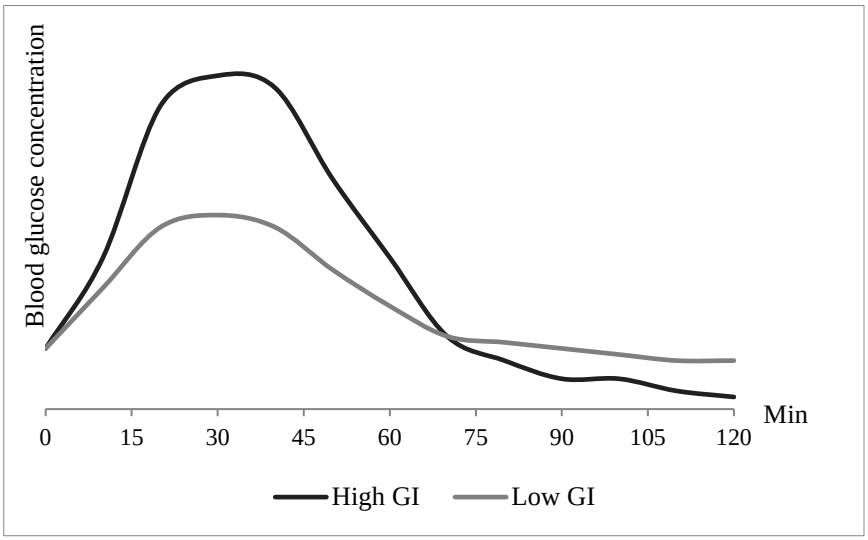


Figure 3. High GI foods cause rapid rise in blood glucose followed by rapid fall in blood glucose while low GI foods lead to a slow increase blood glucose concentration followed by gradual fall in blood glucose (plotted by the author from the concept described by Brand-Miller et al., 2002).

Although evidence from short- and medium-term clinical trials has shown favourable effects of low GI or low GL diets on satiety and glycaemic control (Pawlak, Ebbeling, & Ludwig, 2002), the results have been inconclusive (Raben, 2002). Raben (2002) reviewed 70 studies of different types and found that of 31 short-term studies, low GI foods increased the feeling of fullness more than high GI foods in 15 studies, while no differences or reduced satiety were reported in 16 studies. Similarly, in 20 longer-term studies, only four reported a weight loss on a low GI diet. However, the ideal ad-libitum study of low GI vs. high GI diets has not been undertaken. Over the years, glycaemic response to foods has been studied from various perspectives, however its impact on satiety and the regulation of body weight in the longer term, is a relatively unexplored area (Anderson & Woodend, 2003; Blaak et al., 2012; Ford & Frost, 2010; Niwano et al., 2009).

Effect of dietary fibre

In addition to its non-glycaemic effects, research has shown that dietary fibre has the most impact on reducing energy density and hunger, and therefore would be expected to be the most helpful in reducing energy intake (Rebello, O'Neil, & Greenway, 2016). Dietary fibre in carbohydrate foods dilutes energy density and can reduce hunger partly because it promotes gastric distension by increased secretion of saliva and gastric acid, slows gastric emptying by forming a gel matrix and hence helps regulate energy intake and body weight through multiple hormonal effects (Norden, 2009). An increase in dietary fibre, therefore, could be very helpful in reducing energy intake (Lattimer & Haub, 2010; Rebello et al., 2016). Whole grains, such as oats, have been shown to enhance satiety because of their fibre content (Slavin, 2004). Epidemiological studies have confirmed that dietary fibre and whole grains are associated with a reduction in risk of overweight or obesity (Liu et al., 2003; Williams, Grafenauer, & O'Shea, 2008). Furthermore, evidence from many experimental studies

showed that dietary fibre reduces impaired glucose tolerance, blood glucose and insulin concentrations in people with T2DM (Steyn et al., 2007; World Health Organisation, 2003). Therefore fibre consumption is, unsurprisingly, inversely associated with body weight and body fat.

In recent years, research is inconsistent on effects on satiety between higher and lower fibre intakes. The differences of the long-term and short-term impacts, soluble and insoluble fibre consumptions are not clear. However, to our knowledge, no studies have reported increased hunger or decreased satiety after consumption of high fibre diet (Howarth, Saltzman, & Roberts, 2001).

Effect of fat

Fat is reported to have a weaker satiety value than carbohydrates or protein (Astrup, Buemann, Flint, & Raben, 2002). Evidence has shown that a high fat diet is associated with a higher energy intake. In addition, high fat foods promote consumption because fat has a pleasant and palatable mouthfeel, and enhances some tastes (Norden, 2009).

Effect of protein

Protein in food has a positive impact on satiety. Thus, high protein food has a higher satiety effect than low protein food (Dye & Blundell, 2002; Raben, Agerholm-Larsen, Flint, Holst, & Astrup, 2003). It has been reported that protein induced satiety led to a significant reduction in energy intake and thus is very important for weight loss and weight maintenance (Veldhorst et al., 2008). The World Health Organisation (2003) has recommended that dietary protein should account for 10-15% of energy intake.

Nutrient profiles

Dietary patterns and lifestyle have been shown to be closely related to the health status in general population. It is an ongoing scientific and policy-level challenge to provide evidence-based food and nutrition guidelines for public health (Jomaa, Hwalla, & Zidek, 2016). The World Health Organisation and Food and Agriculture Organisation of the United Nations (2015) have established nutrient intake goals for the general population to prevent diet-related chronic diseases. They recommend that, as a percentage of total energy intake, total fat should be less than 30%, saturated fatty acids should be less than 10%; total carbohydrates should be 55-75%, of which free sugar should be less than 10%; and protein should be 10-15%. Free sugar is a term that refers to all simple carbohydrates (e.g. sucrose) added to foods by the manufacturer or consumers. It has also recommended a sodium intake be < 5 g per day, dietary fibre intake from foods be > 25 g per day, and fruits and vegetables intake be ≥ 400 g per day. Other foods should be whole (unrefined) where possible and highly processed foods minimised.

While populations are encouraged to consume more nutrient-rich foods, the nutrient density has become an important concept (Drewnowski, Fulgoni, Young, & Pitman, 2008). Foods that supply relatively more nutrients and less calories are defined as nutrient dense (Drewnowski & Fulgoni, 2014). Drewnowski (2005) and co-workers have developed a natural nutrient score (NNS) system to evaluate the nutrient-to-calorie ratio of foods. Protein and dietary fibre are the favourable nutrients in the NNS scoring system, and associated with the favourable effects on glycaemia and satiety that are reviewed and discussed in the previous chapters. Another system, NuVal, developed by David Katz and his co-workers (Katz, Njike, Rhee, Reingold, & Ayoob, 2010), uses more than 30 micro and macronutrients to rank foods. Therefore, the nutrient profiling schemes, nutrient density of foods, can be compared and used as the foundation of

dietary recommendations and guidelines, and inform the development of new food products.

Locally, Food Standards Australia New Zealand (FSANZ, 2015) has issued a new food standard for the food industry when making nutrition and health related claims for a packaged food. A nutrient profiling model based on British model (Arambepola, Scarborough, & Rayner, 2008) has been developed (FSANZ, 2015), and web tools are available for the food industry to implement this on packaged foods. The model takes into account for 100 g of the food, the total energy, saturated fat, sugar and sodium in the food as less healthy nutrients are 'bad' points from 0 to 10. The model also takes into account protein, dietary fibre, fruit and vegetable content which are considered as beneficial nutrients, 'good' points from 0 to 5.

Overall score = (total 'bad' points) - (total 'good' points)

A food is classified as 'less healthy' where it scores 4 points or more. The foods that score 4 or less in this system are considered nutrient-dense.

Snack, snacking and health impact

Snack food contributes to more than 20% of our daily energy intake (Bilman et al., 2010; Furchner-Evanson et al., 2010). It has been reported that 53% of women snack several times a day and over 85% of women snack once at least a day (Furchner-Evanson et al., 2010). Traditionally people ate three meals a day at nominally fixed times, usually at four-hour intervals. However, with changes in food supply and lifestyle, eating patterns and behaviour have become more irregular. Snacking, the consumption of food and drinks between the three main meals, has become increasingly more important in daily life (Hess et al., 2016; Savige, MacFarlane, Ball, Worsley, & Crawford, 2007).

It is a challenge for people to adjust their energy intake when snacking to reduce the feeling of hunger until the next meal. Snacks are always categorized according to the eating situations e.g. with coffee, rather than the health properties of foods, e.g. GI, satiety (Bilman et al., 2010). Despite the effort made in the recent years, to date, the effect of snacking behaviour on health is not well researched or understood (Bilman et al., 2010; Njike et al., 2016).

The snack food market in New Zealand

In New Zealand, a study has shown that children who miss breakfast consume more snack foods because these are able to be eaten 'on the go' and are readily obtainable from convenience stores and schools. These snack foods are usually high in fat and sugar, such as meat pies, chocolates, sweets and candies, and soft drinks (Utter, Scragg, Mhurchu, & Schaaf, 2007).

In 2014, the sales value of snack bars in New Zealand was NZ $132 million with muesli bars accounting for NZ $71 million, and is forecast to retain the same sales value by 2019 (Euromonitor International, 2015). In New Zealand, muesli bars are perceived as healthy and are commonly consumed as snack food, and are also a popular choice for the food taken to school. There is a variety of muesli bars available in the New Zealand market. However, most of these muesli bars are high in sugar and saturated fat: are energy dense and low in protein, fruits, nuts and dietary fibre with many E numbered additives. Most snack bars in New Zealand supermarkets do not have good nutrient profiling scores, range from 6 to 22 based on a personal survey (2013) of supermarket packaged snack bars accessed from a range of local supermarkets in Auckland, New Zealand (Appendix E).

Health benefits of oats

In the global production of cereal crops, oat is one of the economically important cereal crops, only exceed by rice, wheat, maize, barley, and sorghum. Oats are a popular foodstuff in many Western countries and are consumed in the form of porridge and as an ingredient in muesli, granola, and similar cereal products.

In recent decades, oats have been perceived a healthy food throughout the world (Meydani, 2009; Pasut, 2012). Oats contain a high concentration of dietary fibre, 9.9% in oatmeal and 14.9% in oat bran. Studies have shown that consumption of oat bran can reduce blood low density lipoprotein concentrations (LDL-cholesterol), and lower the risk of CVD (Meydani, 2009). A number of studies indicated that beta-glucan (a soluble fibre) from oats improves postprandial glycaemic and insulinaemic responses and stabilises blood glucose concentrations (Granfeldt, Nyberg, & Bjorck, 2008), which would benefit people with non-insulin-dependent diabetes and health of the general population (Katz, 2001; Poppitt, van Drunen, McGill, Mulvey, & Leahy, 2007). A high level of beta-glucan fibre lowers the glycaemic impact of food (A. L. Jenkins, Jenkins, Zdravkovic, Wursch, & Vuksan, 2002). Food Standards Australia New Zealand (2015) allows a health claim when a certain amount of high β-glucan oats are present in a product.

Compared to other common cereals, oats generally contain one-third more protein by dry weight. In addition, oats contain high levels of lipids (fats), 5-9%, which provides more energy. The fatty acid composition of oat lipids is of substantial interest due to the nutritional significance of unsaturated fatty acids, such as the essential fatty acid linoleic acid, in human diet (Guo et al., 2014; Katz, 2001). Oats also contain avenanthramides, unique antioxidants, and vitamin E-like compounds, which have been connected with long life and general good health (Meydani, 2009).

Epidemiological and clinical data have shown that the satiating properties of oats are associated with the prevention of weight gain and subsequent obesity (Katz, 2001; Schuster, Beninca, Vitorazzi, & Morelo, 2015). As such, the multiple health benefits of oats should be promoted to increase consumer awareness. The evidence supports the encouragement of the consumption of oats as a regular part of the diet.

Branding, labelling and consumers perception

In recent years, health cautious consumers have been making active efforts to consume healthier foods. However, successful marketing of healthier food products has challenges such as lack of taste appeal, sustainable ingredients and proven product effectiveness.

Many consumer studies have confirmed that extrinsic product hints (e.g. packaging) influence sensory evaluation of foods (Mueller & Szolnoki, 2010). Mueller and Szolnoki (2010) reported that labelling and branding have a strong impact on product liking. In recent years, labelling, and front-of-pack labelling in particular, has been introduced as an intervention to encourage healthier food choices (Steenhuis et al., 2010; van Herpen & Trijp, 2011). However, some studies reported that consumers pay little attention to these labels, which limits their effectiveness (Bialkova & van Trijp, 2010). Bialkova and van Trijp (2010) identified the key factors determining consumer attention to labels: the size of display, the colour scheme, familiarity with the label and how the label is presented. To date, very little is known about the influence of labelling on actual and potential compensatory eating behaviours (Steenhuis et al., 2010).

Summary

The prevalence of preventable chronic diseases is increasing worldwide. Rapid changes in environment and dietary behaviours, and physical inactivity have been suggested as the likely causes.

There is evidence that good glycaemic control is a primary goal in the prevention and management of hyperglycaemia. The GI concept might be a tool for diet education in both health and disease management. However, a range of factors affects the GI and GL values of foods. For example, a food with a high fat content may present a reduced GI, but is likely to be energy dense. Nevertheless, the evidence is clear that the GI and GL concepts are useful tools that could be applied together to support the food and nutrition guidelines.

Energy density is obviously associated with energy intake. Research has suggested that in the short term, low energy dense foods increase satiety, decrease feeling of hunger and reduce energy intake. Most of dry food products, for example muesli bars, are usually energy dense due to the nature of low water content and relatively high energy density ingredients such as dried fruit, nuts and desiccated coconut. Fruits, nuts and whole grains are also nutrient dense. Therefore, reformulation of foods to increase nutrient density and relatively reduce energy density without the addition of food additives and preservatives could provide an effective approach for the improvement of the nutrient profile of the food supply, and the prevention and treatment of obesity.

In respect of the food industry, a wider availability of food with nutrition and verifiable health claims could help consumers to make healthier choices. This could be achieved by food reformulation to make food products, which are low in refined starch, and high in protein, dietary fibre, and fruits and nuts.

The development of a commercially viable healthier muesli-based snack bar is the topic of this research.

Question and aims of the thesis

This literature review lead to the overarching question: Can a healthier snack bar prototype branded “Nothing Else” be formulated, produced and accepted by consumers as a food that they will eat? To assess the healthiness of the bar could the bar have a lower glycaemic impact and prolong satiety compared with other bars and over a period of time change habitual snacking behaviour? The specific objectives of the series of experiments for a snack bar that meets the Nothing Else brand criteria and the nutrient profiling criterion for health claims were:

- Undertake laboratory trials for ingredients selection, water activity control, shelf stability and formulation finalised to be compatible with the production line at AB Foods Ltd. (Chapter 3)
- Investigate the effects of branding, ingredients and nutrition information on consumer liking of the Nothing Else snack bar, compared to top snack bars brands in New Zealand. Further, to investigate the relative importance of healthiness, taste, naturalness of foods to consumers (Chapter 4)
- Investigate the glycaemic and satiety effects on consumption of the Nothing Else snack bar in comparison to two top-selling commercial bars. Further, to investigate the correlation between blood glucose concentration and satiety; and the correlation between nutrient composition and physiological effects of snack bar (Chapter 5)
- Investigate the effects of the Nothing Else bar on snacking habits and haemoglobin A1c (HbA1c) with a 6-week intervention (Chapter 6)

Food ingredients were screened based on their nutritional and health related properties and the nutrient profile model was used as a tool to develop a prototype snack bar. Nutrient factors studied include energy, carbohydrate, fat, protein, and dietary fibre.

The consumer study evaluated the branding and product acceptability. The *in vivo* studies investigated if the developed snack bar has a lower glycaemic impact and a higher satiety effect in comparison with similar commercial bars; and explored if there was an association between the nutrient composition and the physiological *in vivo* glycaemic responses and satiety effects.

The Nothing Else snack bar, made from fewer than eight natural ingredients, with a lower GI, a reduced energy density and an increased nutrient density, was therefore developed to meet the needs of consumers wanting healthier foods. The Nothing Else label has been developed by Dave Brown, School of Communication Studies, AUT. The intellectual property and licensing around the labelling and production of the bar comes under AUT Commercialisation and Innovation Centre.

It was hypothesised that in comparison with similar food products, the developed prototype snack bar would have a healthier nutrient profile; be acceptable in sensory evaluation; have a lower effect on blood glucose response and induce similar or better satiety; have a potential to improve habitual snacking behaviour and public health in the longer term.

Chapter 3

Study One: Development of the Nothing Else Bar

Materials, Experimental Approach and Snack Bar Development

Muesli is a breakfast food mainly composed of uncooked rolled oats, fruits and nuts. It was introduced by Swiss physician Maximilian Bircher-Benner around 1900 as a therapy for his patients. Muesli became popular in the 1960s in Western countries due to increased interest in healthy diets ("Muesli," 2016). A muesli bar is identical to the normal form of muesli in composition, but is pressed and baked into a bar shape in contrast to a loose, breakfast cereal. The bar shape allows a more convenient snack.

In New Zealand, muesli bars are commonly consumed as snack food and also a lunchbox option for school children. There are varieties of muesli bars available on the New Zealand market. However, not all muesli bars are necessarily healthy food. Most of these muesli bars are high in calories, refined sugar and saturated fat, with many E numbered additives and preservatives included.

In this study, a healthier muesli-based snack bar was developed. The developed snack bar met the criteria listed below:

Compared to other New Zealand top selling muesli bars

- Meets the requirements of the Nothing Else brand
- Has a healthier nutrient profile
- Is equally acceptable in taste
- Has a good shelf stability
- Induces similar or better satiety
- Has a lower effect on blood glucose concentration

Initial trials for snack bar formulation

Materials and methods

Raw ingredients used in laboratory trials were provided by AB Foods Ltd., Auckland. On occasions, some specific ingredients needed for trials were also sourced from supermarkets in Auckland. Equipment used in the development of snack bars was available on site at AB Foods Ltd., and at the food laboratory in School of Science, Auckland University of Technology.

The potential ingredients were selected prior to the laboratory trials. The ingredient selection met the requirement of the Nothing Else brand, eight or fewer, all perceived as natural, and no synthetic additives, and predicted to contribute favourably to the glycaemic load. The ingredients also had good nutritional profiles (FoodWorks, Xyris, Australia), as well meeting the constraints of production facilities at AB Foods Ltd., Auckland.

The role of ingredients in snack bar formulations

The main ingredients used in snack bar formulations were rolled oats, oat bran, dried fruits, nuts, and binding agents. Other ingredients such as oils, sweeteners and spices are also used but in small amounts.

The primary component structure of the developed snack bar was rolled oats. Like other grains, the oat kernel comprises three structural layers: the bran, the germ, and the endosperm. Oat bran contains a majority of the biologically active compounds including dietary fibre, minerals, vitamins, and essential fatty acids. The germ is rich in polyunsaturated fatty acids (PUFAs). The endosperm is the starchy part but also contains protein (Slavin, 2004). Oats are contemporarily considered a healthy food with many already known health benefits, such as modulation of glucose metabolism, reduction of low density lipoprotein, and reduction of satiety (Slavin, 2004; Tapola,

Karvonen, Niskanen, Mikola, & Sarkkinen, 2005). The health benefits of oats are discussed in more detail in the previous chapter (page 30).

The dried fruits, such as apricots, raisins, dates, and cranberries, provide good flavour and antioxidants: apricots provide a popular flavour, cranberries are rich in antioxidants, and raisins and dried dates are very good binders.

The nuts, such as almonds and hazelnuts, offer healthy fats and give pleasant aroma and texture. Additionally, nuts are rich in protein, fibre, and essential minerals, and are good sources of vitamin E and vitamin B_2.

The role of binding agents is crucial in snack bar formulations. Usually sugar syrup and honey are used as binders, but they adversely contribute to the nutrition profiling score. Therefore, unsweetened apple puree, banana, egg white and potato starch were considered in the initial trials of snack bar production as alternative binders. While egg white adds quality protein, it could be associated with allergic and microbiological problems. This was considered, but the initial trials went ahead with egg white which was commercially available.

Cinnamon is commonly used as a spice and also a natural preservative due to antifungal, bactericidal and larvicidal properties of cinnamon oil (Dweck, 2003). In addition, health benefits of cinnamon include lowering cholesterol level, blood sugar regulation, anti-clotting properties and cancer prevention ("Ten health benefits of cinnamon," 2006). *In vitro* and *in vivo* animal studies have demonstrated the blood sugar regulation properties of cinnamon (Akilen, Tsiami, Devendra, & Robinson, 2012). Other researchers have suggested that consumption of cinnamon is associated with lowering fasting plasma glucose (FPG), LDL-cholesterol, and triglyceride levels (Akilen et al., 2012; Allen, Schwartzman, Baker, Coleman, & Phung, 2013).

Initial trials of snack bar production

Initial trails were conducted in a kitchen on site at AB Foods Ltd., and the food laboratory at AUT. For each trial, eight or fewer natural ingredients were selected from the ingredients list (Table 1). The proportions of the main ingredients including rolled oats, dried fruits and nuts were adjusted based on their food energy and nutrient values. Apple puree, banana, and egg white were used as binders.

The dry ingredients were placed into the bowl of a domestic Kenwood food mixer to mix. Honey, sunflower oil and egg white were added 2 minutes after. All the ingredients were then mixed in the mixer for 3-5 minutes until well combined. The mixture was transferred into a baking pan lined with baking paper, spread evenly and pressed flat to approximately 1 cm thickness, and then baked in a preheated fan oven (APV Baker Pty., Luke, Australia) for 15 minutes at 160°C. After removal from the oven, the baking pan was left to cool at room temperature for 30 minutes before being cut into bars, approximately 40 g per bar.

Table 1. List of ingredients and suppliers

Ingredient	Supplier
Rolled oats	Harraways New Zealand
Oat bran	Woolworths Australia
Almonds	Pak'nSave, Auckland
Apricots	Sun Valley Foods New Zealand
Cranberries	Pak'nSave, Auckland
Dates	Sun Valley Foods New Zealand
Raisins	Woolworths New Zealand
Apple puree	Pam's, Pak'nSave, Auckland
Banana	Pak'nSave, Auckland
Manuka honey	Comvita New Zealand
Sunflower oil	Pam's, Pak'nSave, Auckland

Egg white	Woolworths New Zealand
Cinnamon (ground)	Cerebos Gregg's New Zealand
Ginger powder	Cerebos Gregg's New Zealand
Gelatine	McKenzie Foods Australia

These ingredients were trialled in different combination and composition to produce a mixture with the ability to be held together and be low in water activity (a_w < 0.7) after baking.

Physical attributes of the snack bar

The physical attributes of foods including water activity, moisture content, colour, texture and sensory properties are important factors affect the quality, shelf stability and acceptability of food products. The following sections explore the methods for evaluation of these factors for the developed bar.

Water activity

Water, a major constituent in food, is critically related to the physical properties of foods. Water is an essential element for microbiological growth, and supports chemical reaction and enzymatically catalysed reaction in food products ("Water activity," 2016).

Water activity (a_w) is a measure of the availability of water for microbiological growth and other activities, and is defined as the ratio of the equilibrium vapour pressure of the sample (p) to the equilibrium vapour pressure of pure water (p_0) at the same temperature ("Water activity," 2016). By contrast, moisture content or water content is a measure of the total amount of water in a substance relative to the substance itself. Water activity is positively correlated with moisture content ("Water activity," 2016). The literature on microbial growth suggested that microbial growth would be minimised if a water activity below 0.7 were achieved (Labuza, 1970; Rockland &

Beuchat, 1987). When water activity exceeds 0.7, fungal growth can readily occur (Labuza, 1970) (Figure 4). Fungal/yeast growth is the most likely contaminant for a backed product such as a snack bar.

Water activity was measured using an AquaLab CX-2 water activity meter (Decagon Devices, Pullman, WA USA). A crumbled sample (3 g) from a well-mixed sample was put in the sample jar, and then placed into the chamber assembled at 20°C. The measurement was undertaken in triplicate.

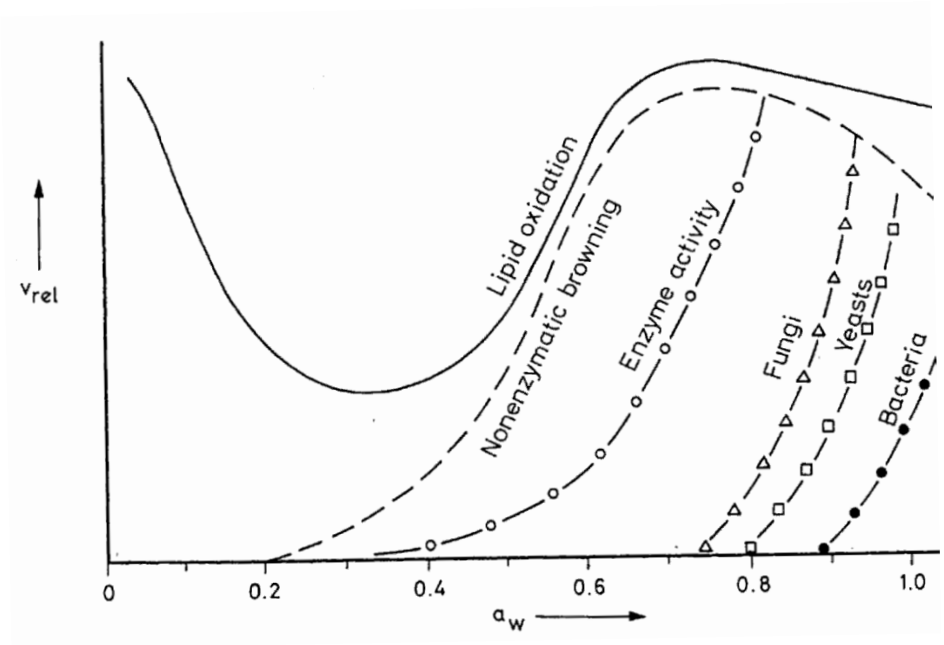


Figure 4. Stability map of foods as a function of water activity (modified from Labuza, 1970), where v_{rel} means relative reaction velocity, a_w is water activity.

Shelf stability

The shelf life of a food is the period of time for which it remains safe and suitable for consumption (Ministry for Primary Industries NZ, 2016). The common issues with product deterioration include rancidity, loss of nutrients, browning, and changes in texture and flavour. Spoilage and pathogenic bacteria cause spoilage and in some cases

food poisoning. For instance, *Bacillus spp.* are more likely to be associated with cereals and baked goods.

Formulation and processing variables which can be used to control deterioration include: (1) moisture and water activity; (2) pH; (3) heat treatments; (4) emulsifier systems; (5) preservatives and additives; and (6) packaging. In the current study, water activity control and packaging design were critically important, due to the fact that all ingredients are natural, and no preservatives and additives were used.

In the industrial production of the snack bar, the product is baked at a high temperature (160°C), which should destroy any airborne microbes. In addition, food hygiene measures such as washing hands regularly and wearing a cap and protective clothing are followed in preventing contamination. AB Foods is a good manufacturing practice (GMP) licensed factory, which has implemented good manufacturing practice for food quality and safety management.

A shelf life trial was conducted in a food laboratory at AUT. The test foods were kept under three temperature conditions: 4˚C, room temperature, and 30˚C. Thirty bars were kept for each condition. In the first two months, the samples were checked fortnightly. After two months, the samples were checked once a month. The duration of the trial was six months. At each time point, three bars from each condition were examined for appearance, colour and taste.

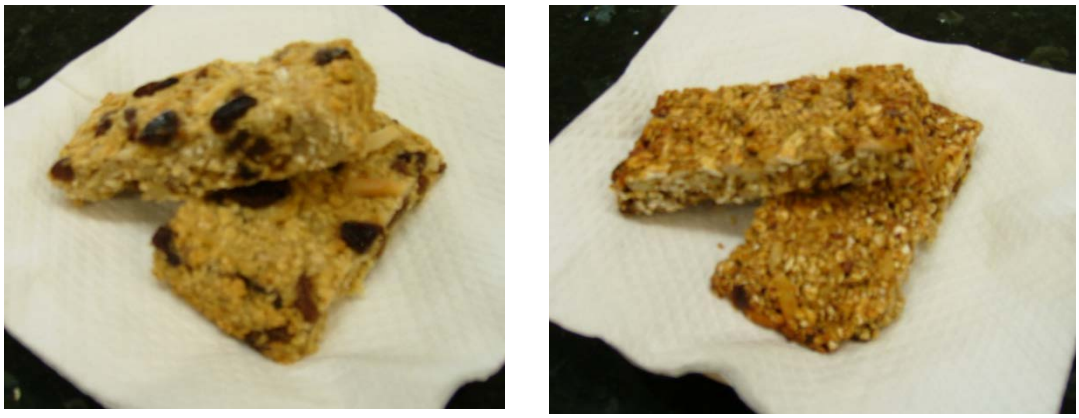
The procedure and formal shelf life testing for the industrial production was advised and conducted by AsureQuality Ltd., Auckland, New Zealand. Water activity, total moisture, pH and yeast and mould colony forming units were measured at regular intervals. The shelf life of the snack bars ($a_w < 0.7$) was determined to be 6 months.

The preliminary results of the trials

Sixteen formulas were trialled to evaluate the basic function of the binding agents and their contribution towards the formulations, 16 prototype bars were therefore produced. The sixteen prototype bars were informally evaluated for four quality attributes: visual appearance, texture, taste, and water activity. The panel comprised the author, a nutritionist, a marketing professional, and two experienced bakers at AB Foods Ltd.

The preliminary results showed that the snack bars made with apple puree or banana as binder had good taste, but the colour was too light (Figure 5a). Honey was a good binder, but the quantity needed when used alone elevated the sugar content above the predetermined limit. The bars made with gelatine as a binder had a very good texture, but in consideration of vegetarians, gelation is not a good option as it is an animal product.

The water activity of snack bars was also measured. As expected, bars made with apple puree or banana had a higher moisture content and concomitantly a higher water activity, as well as a lighter colour.



(a) (b)

Figure 5. Preliminary production of the snack bar. (a) Bar using apple puree as binder, (b) Bar 12 using dates as binder.

Bar 12 was considered as the best one because of the golden colour (Figure 5b), pleasant taste, chewy mouth-feel, and a lower water activity (a_w = 0.68). Bar 12 was formulated with rolled oats, almonds, dates, honey, egg white, sunflower oil, and cinnamon. Dates are very sticky when blended, so a very good binder. Egg white is also a good binder and with sugars aids the Maillard reaction. Honey contributes to the sweetness and also works as humectant. Sunflower oil helps maintain a moist texture and also contributes to binding. Moreover, the nutrient profiling score of recipe 12 was good (NPS -2).

The formulation of bar 12 was repeated several times to check consistency. The results were consistent with regards to colour, texture, taste and moisture loss. Therefore, the potential ingredients were narrowed down and the recipe 12 (Table 2) was accepted as a basic formula.

Table 2. Formulation of snack bar 12

Ingredient	Quantity (g)	Proportion (%)
Rolled oats	100	35
Almonds	30	14
Dates	45	21
Honey	5	2
Sunflower oil	5	2
Egg white	30	14
Cinnamon	3	1
Total	218	

Informal consumer feedback

Informal consumer feedback was sought to qualitatively explore the acceptability of the Nothing Else snack bar to consumers. Ethics approval was not obtained for this testing, as it is a preliminary interaction where the research aims had not been set. No personal information was collected, and the feedback was anonymous.

Samples and drinking water were provided in public places: Sport and Fitness centre at AUT Akoranga campus and Sport Waikato, New Zealand. Participants were asked to respond to open questions about the snack bar and possible price. The Nothing Else logo and nutrition information of the product were shown and explained to participants. Fifty potential consumers including 30 members of the never2old group provided responses. The never2old is a gymnasium-based training programme for people aged ≥ 60 years at AUT Sport and Fitness. Comments were received in writing on the questionnaires or through emails. Positive and negative comments were transcribed using key words concerned with nutrition, health and price and were analysed using thematic approach.

Key observations

What about the snack bar? Why would you eat it or not?

Participants commented that the bar was healthy, filling, tasty, and had good flavour, nice texture, good nutrition value, and a good fibre content. Furthermore, it was suggested that the snack bar could be consumed as a snack or a mini-meal. It would provide good options for children and active outings. One third of participants found the snack dry and suggested that the perceived moisture needed to be improved. Some participants suggested replacing cinnamon with ginger. Twenty-four participants (48%) clearly stated that they would eat or buy the bar, while four participants (8%) said they would not.

What would you pay for a bar like this?

Most participants suggested the price should be $1.50 to 2.00 when sold individually (40 g) and also suggested the snack bar is suitable for health conscious adults or athletes.

Learnings from consumer feedback

Consumer feedback indicated that Nothing Else logo is simple, easy to read and understand, with all ingredients list in the front pack inside the circle providing clear and effective information to consumers as to what they are actually eating. Participants in general liked the taste and flavour despite the perception of dryness. Twenty-four out of 50 participants clearly stated that they would eat or buy the snack bar. The acceptable price was suggested to be $1.50-2.00 at a serve size of 40 g. The informal consumer feedback revealed that the descriptive ingredients generally were associated with a favourable effect on consumer liking. The results from never2old group showed a strong connection between health attitude, consciousness, interest and consumer liking. It was concluded that the Nothing Else snack bar has the potential to find a niche in the snack bar market.

Formulation refinement

The main problem identified from informal consumer feedback was the dryness. Therefore, the formulation was refined to improve the perceived moisture, mouthfeel. Fat can function as a barrier to manage the moisture flow in and out of food products (Berry, 2012). In addition, fat also acts as a flavour precursor that affects mouthfeel (Pozo-Bayon, Guichard, & Cayot, 2006). Experimental trials were undertaken to increase or decrease the contents of honey and sunflower oil by 1% to explore the variables. The formulation was finalised based on mouthfeel and nutrition profile. In the final formula, honey and sunflower oil content was increased from 2 to 6%. Rolled oats

were partially replaced by oat bran to increase the fibre content. The final oats: oat bran ratio was 80: 20. The water activity of the prototype bar was 0.64.

Nutrient profile

The nutrient profile of the refined formula was evaluated using the FoodWorks version 7 (Xyris Pty Ltd., Australia). The results indicated that the snack bar contained relatively low energy, low saturated fat, and low sodium. The protein, fibre contents were relatively high (Table 3).

Table 3. Nutrition analysis of snack bar formula, nutrition facts

	Quantity per 100g
Energy (kJ)	1544
Protein (g)	11.6
Total fat (g)	17.1
Saturated fat (g)	2.1
Carbohydrate (g)	44.9
Total sugar (g)	20.3
NSP fibre (g)	8.2
Sodium (mg)	38

The nutrient profiling score was -1.

NSP: non-starch polysaccharide

The glycaemic index of the prototype bar

The GI of the Nothing Else prototype bar was tested in the Nutrition Research laboratory at AUT by Dr Bruce Donaldson and is briefly reported below for completeness.

Materials and methods

The Nothing Else prototype bar was prepared before the testing at a portion size containing 25 g of available carbohydrates. A standard 25 g glucose drink (Thermo Fisher Scientific, Australia) was used as a reference food.

Twelve healthy subjects were recruited. Each participant was asked to attend the laboratory on two occasions, once to test the glucose drink, once to test the Nothing Else bar. Ethics approval was provided by AUT Ethics Committee (Reference no. 14/144). Participants were provided with written information and the opportunity to ask questions before signing written consent to participate.

The GI of the bar was measured following the international standard method ISO 26642:2010(E) (International Organisation for Standardisation, 2010). Capillary blood samples were collected from finger pricks using sterile disposable lancets. The blood glucose concentration was measured using HemoCue Glucose 201+ analyser (HemoCue AB, Ängelholm, Sweden).

The test was conducted in the morning after 10-12 hours of overnight fast with standardisation of physical activity and the last meal of the previous day. The fasting blood glucose concentrations were measured at 0 and 5 minutes. The mean of the two readings was used as the baseline. Following the baseline tests, a test food containing 25 g of available carbohydrate was consumed within 10 minutes. Participants' capillary blood samples were analysed for glucose at 15, 30, 45, 60, 90, and 120 minutes after the

start of the ingestion of a snack bar. Participants were asked to remain seated during the course of the tests.

Statistical analysis

Average fasting and postprandial blood glucose concentrations were plotted against time for each test food. The glucose iAUC was determined geometrically by applying the trapezoid rule (International Organisation for Standardisation, 2010). The mean iAUC of the reference food and the mean iAUC of the Nothing Else bar was used to calculate the GI of the Nothing Else prototype bar. The GI of the snack bar was calculated using the formula below.

$$GI = \frac{\Delta AUC \text{ of 25 g carbohydrate from the snack bar}}{\Delta AUC \text{ of 25 g glucose}} \times 100$$

Results of glycaemic index testing (in vivo)

The GI of the Nothing Else prototype was 52 (n = 12).

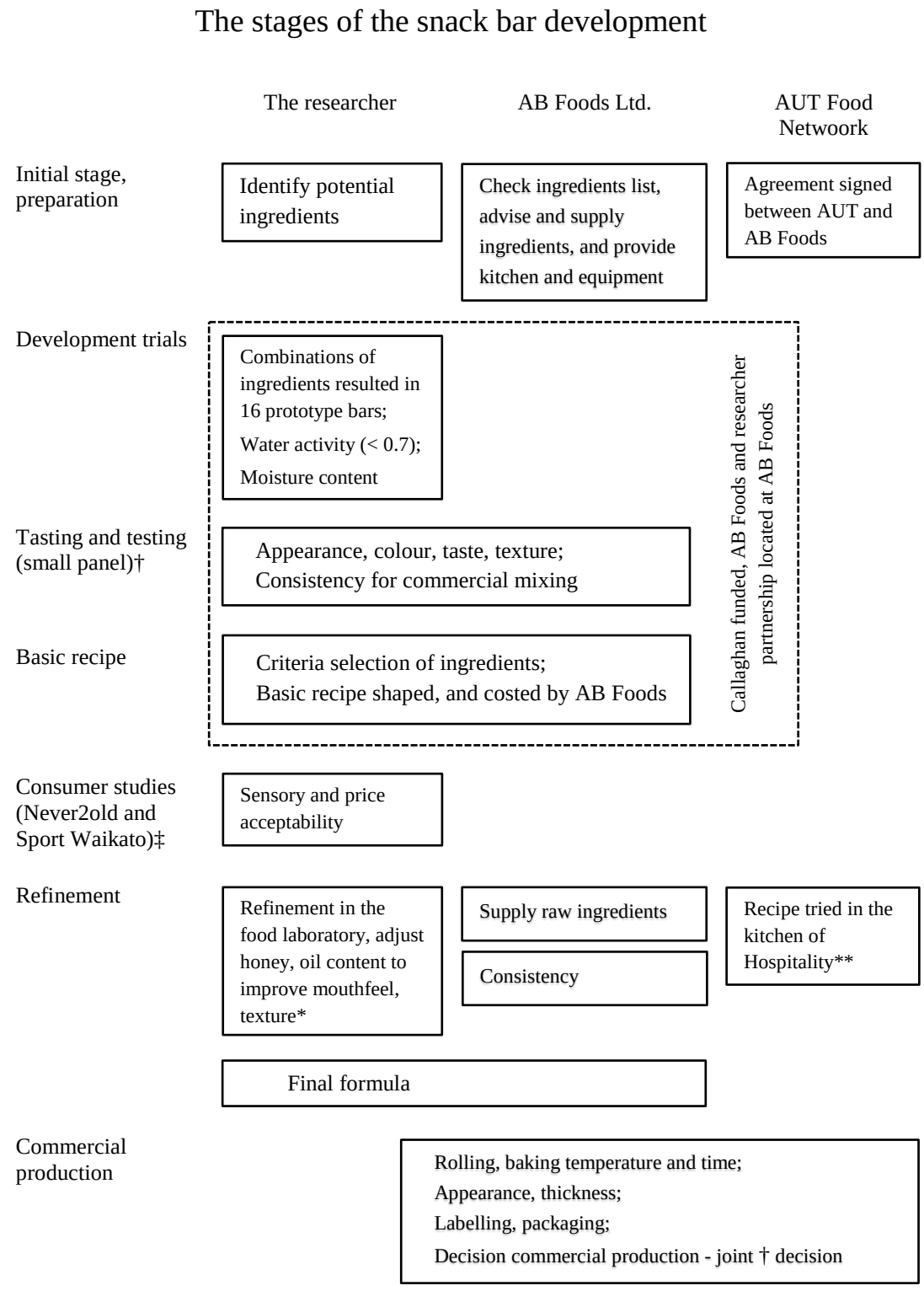
Costing

While branding and healthiness of food are important factors related to food choices (Fernqvist & Ekelund, 2014; Provencher & Jacob, 2016), consumer purchase intent is also influenced by price, particularly in low income populations (Steenhuis, Waterlander, & de Mul, 2011). Therefore, a reasonable market price of a healthy food requires special pricing strategies.

For the Nothing Else bar, all ingredients are readily available and inexpensive items except for Manuka honey. In addition, due to the relatively short shelf life (6 months), this would slightly increase the price of the snack bar. The estimated market price of a 40 g bar is approximately $2.00.

Summary of the process

The development of the Nothing Else snack bar was a cross-discipline collaboration between researchers, an academic institution (Auckland University of Technology), and the food industry (AB Foods Ltd., Auckland). The process included potential ingredients selection; initial development trials with different combinations of ingredients at home, in the test kitchen, and in the food laboratory at AUT; tasting and testing product informally; and formulation refinement. The development was staged using a systematic process and approach (Figure 6) where identification of the goal, discussion, action, review, and revision were followed and all partners participated. This study was a model, a proof-of-concept where a commercially viable healthier snack was produced in partnership with the food industry.



†Mary Yan, Elaine Rush, Dave Brown, Peter Tan, Janice Tan
‡Mary Yan, Elaine Rush
*Mary Yan, Bruce Donaldson
**John Kelleher and the team

Figure 6. Diagram of the stages of the development of the Nothing Else snack bar.

Chapter 4

Study Two: Consumer Study

Branding, Ingredients and Nutrition Information: Consumer Liking of a Healthier Snack

Abstract Taste appeal, sustainable ingredients and valid health claims are challenges for successful marketing of healthier food products. This study was designed to compare the effects of branding, ingredients and nutrition information on consumer liking towards a prototype of the Nothing Else healthier snack bar with the top three brands of New Zealand snack bars, and another product with a good nutrient profiling score. Sixty-four consumers were recruited to evaluate the five snack bars. Participants initially blind-rated on visual analogue scales their liking scores in relation to colour, taste, flavour, texture and overall liking. Packaging for the products was then presented alongside each of the five products and participants rated their liking scores for a second time. Participants also ranked the five products from 1 to 5 for healthiness, taste, naturalness, and purchase intent if prices were the same. In both blind and informed tests, the Nothing Else bar was the least liked snack bar among all the tested samples. However, after the packaging for the products was presented, overall liking of the Nothing Else bar increased by 14% (p = 0.023), while overall liking for the four commercial products were unchanged. While the most popular commercial bar was ranked the highest for taste and purchase intent, the Nothing Else bar was ranked the highest for the healthiness and naturalness. Our findings confirmed that the branding and health related nutrition information could improve consumer liking and brand perception particularly if backed by marketing.

Keywords: brand perception, healthier snacking, Nothing Else, sensory properties

Introduction

In response to the growing consumer demands for healthier foods (Siro, Kapolna, Kapolna, & Lugasi, 2008), many food manufacturers have reformulated established brand products. However, taste appeal, sustainable ingredients and valid health claims are challenges for successful marketing of healthier food products. While taste is the most important factor for consumer perception in general (Fernqvist & Ekelund, 2014), healthiness is suggested to be another factor which influences consumers' choice (Carrillo, Varela, Salvador, & Fiszman, 2011; Provencher, Polivy, & Herman, 2009; Roininen, Lahteenmaki, & Tuorila, 1999). Extrinsic product factors, such as region of origin of a wine can influence consumer perception (Mueller & Szolnoki, 2010). Mueller and Szolnoki (2010) reported that labelling and branding have a strong impact on product liking. In recent years, nutrition information, and front-of-pack labelling particularly, have been introduced as ways to encourage healthier food choices (Steenhuis et al., 2010; van Herpen & Trijp, 2011). However, consumers pay little attention to this information which limits its effectiveness (Bialkova & van Trijp, 2010).

Snacking between main meals has become increasingly important in daily life (Savige et al., 2007). However snacking behaviour has not been well researched or understood (Bilman et al., 2010). Snack foods usually are categorized around the eating situations, rather than their health properties (Bilman et al., 2010). Although 'muesli-style' snack bars are regarded as being healthy, in a survey undertaken by the primary researcher of this study (data not published), most of the snack bars in New Zealand supermarket are high in sugar and fat, low in protein, fruits, nuts and dietary fibre, with many E numbered additives. They do not have nutrient profiling scores as defined by Food Standards Australia New Zealand (2012) that allow them to make a health claim. In New Zealand, the score should be 4 or less but in the survey we found that scores range from 6 to 22.

The Nothing Else, a brand created at Auckland University of Technology, New Zealand (D. Brown et al., 2015), was introduced in 2010 with the intent to promote sustainable consumption. Since 2013, the Nothing Else healthier snack bar has been developed, and the resultant almonds and dates bar was the third product of the Nothing Else brand. The Nothing Else bar uses eight perceived natural ingredients, is high in fibre and low in sodium according to FSANZ (2012), and has a low glycaemic index of 52 (data not published). An informal sensory trial showed that potential consumers found the taste, healthiness and natural ingredients as favourable features of the bar (D. Brown et al., 2015).

This study aimed to investigate the effects of branding, ingredients and nutrition information on sensory acceptability/liking of the Nothing Else snack bar, compared to top snack bars brands in New Zealand. The secondary aim was to investigate the relative importance of healthiness, taste, naturalness of foods to consumers. The main hypothesis was that branding, ingredients and nutrition information would influence consumer liking.

Materials and Methods

Experimental approach

Sensory evaluation (Lawless & Heymann, 2010) describes procedures in food manufacturing and technology to determine the acceptability and consumer responses towards the quality of new food products. Direct consumer testing is where sensory information is collected directly from individuals without formal training in sensory evaluation. The test enables manufacturers to predict likely market behaviour (Giacalone, Bredie, & Frøst, 2013). In addition, consumer opinions can be incorporated as part of the refinement and optimal design of food products (Lawless & Heymann, 2010). Consumers rate their liking for various attributes of a given food product on a

defined scale (Lawless & Heymann, 2010; Schutz, 1999). A scaling method with low inter-individual variability will allow more sensitive tests and thus a lower risk of missing a true difference (Lawless & Heymann, 2010). Unstructured horizontal line scaling with only the endpoints marked with short line segments was adopted for the current study because the visual analogue scale allows consumers choice to be more continuous and therefore less limited.

Participants

Sixty-four participants (Table 4) were recruited for the present study. Participants were comprised of staff members and students from two tertiary education institutes in Auckland, New Zealand. The demographic of this population meant that about half the participants were of Asian origin (Table 4). Eligibility criteria required that participants were 18 years or older, consumed snack bars at least once a week, and had no known allergies to food ingredients including nuts, gluten, egg, and milk. The sample size to measure the degree of liking of consumers by the use of visual analogue scales (VAS) was determined from the usual requirement for fifty or more untrained persons (Lawless & Heymann, 2010; "Sensory analysis," 2015). The effective sample size, nevertheless, was based on what is seen during the course of the study (Cohen, 1988). Ethics approval for this study was provided by Auckland University of Technology Ethics Committee (Reference no. 13/184).

Sample preparation for sensory analysis

The Nothing Else prototype bar was prepared in the food laboratory in School of Applied Science, AUT University. Four commercial products included the three top New Zealand brands of snack bars (45% of the market share, Euromonitor International, 2015), and another product that was similar in nutrition profile score to the Nothing Else bar (Table 5). All commercial products were purchased from local supermarkets in Auckland, New Zealand.

Table 4. Demographic characteristics of the 64 participants

	Total	Age 20 to 29 yrs	Age ≥ 30 yrs
Gender			
Men	23	13	10
Women	41	28	13
Ethnicity			
Asian	38	31	7
Non-Asian	26	10	16

Table 5. Samples for consumer liking testing

Code	Brand	Market share[1], MAT[2] to (%)	Nutrient profiling score[3]
B1	Brand 1	15.9	11
B2	Brand 2	15.9	12
B3	Brand 3	14.7	15
B4	Brand 4		1
NE	Nothing Else		-1

[1]Ranked in order of sales value in NZ in 2015 (Euromonitor International, 2015)

[2]MAT: moving annual total

[3]Derived from nutrient profiling model (FSANZ, 2012). A food with a score > 4 is unable to make health claims.

Nothing Else bar ingredients (in descending order by % weight)**:** Rolled oats, almonds, dates, egg white, oat bran, honey, sunflower oil, cinnamon. **B1 ingredients:** Peanuts, almonds, dates, sultanas, milk powder, cocoa powder, vegetable oil, soy lecithin, citric acid, brown sugar, puffed wheat, glucose, sugar, honey, sunflower seeds, glycerol, maltodextrin. **B2 ingredients:** Peanuts, almonds, glucose syrup, milk chocolate, sultanas, sugar, wholegrain oats, rice crisps, malt extract, vegetable oil, flavours, soy lecithin. **B3 ingredients:** Sultanas, rolled oats, wheat flour, butter, milk powder, desiccated coconut, preservative, raw sugar, honey, sugar, oat bran, whole egg powder, raising agent, flavour, salt. **B4 ingredients:** Wholegrain oats, wheats, raw sugar, sugar, honey, barley malt extract, wheat fibre, gelling agent (pectin), vitamin (niacin, thiamine, riboflavin, folate).

Snack bars were cut into a 2 x 2 cm^2 pieces and were presented to the consumers at room temperature (20 °C) on white, covered food grade plastic containers under white light. The samples were identified by individual three digit codes, which were randomised, and counter balanced to order of presentation using a Latin square design (Macfie, Bratchell, Greenhoff, & Vallis, 1989) to reduce participant and researcher bias.

Experimental protocol

Participants were asked to attend test sessions at least two hours after breakfast in the morning. Each participant was seated at a table separated by partitions to ensure they did not interact or influence other participants. After reading the study information and asking any questions, participants were asked to sign the consent form before the testing started.

A three stage evaluation procedure was applied: a) sensory evaluation in a blind condition; b) sensory evaluation with the knowledge of branding, ingredients and nutrition information; c) ranking of the importance of healthiness, taste, and naturalness to consumers.

In the first stage blind condition, the Nothing Else prototype was presented twice to measure the reliability of participants. Each participant tasted six samples in a blind condition and evaluated his or her liking in relation to colour, taste, flavour, texture, and overall liking on five 100 mm unstructured line scales anchored at dislike extremely (left end) and like extremely (right end) (Figure 7). Participants were asked to rinse their mouth with water in between tasting each sample.

Figure 7. Line scaling for measuring consumer liking/disliking in relation to sensory attributes on a 100 mm visual analogue scale (VAS)

In the informed condition, five samples were presented to participants together with the actual front- and back-pack labels showing the brand, the name of the bar, all the ingredients and nutrition information. For all products, the labels and nutrition panels were colour printed and presented in the same format. Each participant tasted the five samples and evaluated his or her liking in relation to colour, taste, flavour, texture,

and overall liking again on five unstructured line scales. When participants completed this, they were additionally asked to rank the perceived healthiness, taste, and naturalness and purchase intent each from 1 to 5, with 1 being the lowest and 5 being the highest ranking if prices were the same for the snack bars. Participants were also asked to state the importance of healthiness, taste and naturalness from 1 to 5, with 1 being not important and 5 being very important.

Data Analysis

Distance data, to the nearest mm, was measured using a digital calliper (Warrior, Canada) from the left hand anchor point. To compare the repeat measures of the Nothing Else bar two tailed paired *t*-test was used. The mean value of the replicate tests for each attribute of the Nothing Else bar was used in the comparison with the four commercial bars. Separately for blind and informed tests, the means of hedonic liking on 5 sensory attributes (overall liking, colour, taste, flavour, and texture) were calculated and statistically tested using one-way analysis of variance (ANOVA) to determine if a statistical difference existed at $p < 0.05$, Tukey's post-hoc test was then used to identify which specific means were significantly different. Friedman test was carried out for rank sum total (sum total of ranking each of all participants) data on perceived healthiness, taste, naturalness, and purchase intent. Multiple pairwise comparisons with Bonferroni correction were carried out in order to identify statistical separation among the sum ranking total. The effects of age and ethnicity on liking was analysed using two-way ANOVA. The univariate analysis in this study was carried out using SPSS version 22.01, 2013 (IBM Corporation, NY, USA). Multivariate analysis in this study was carried out using XLSTAT version 2013.4.08 (Addinsoft, USA).

Results

When the Nothing Else bar was presented to the 64 participants as two of six randomised samples in a blind test, there was no meaningful difference between the mean values of liking for the 5 sensory attributes. For instance, there was only, on average, a 0.5 mm difference for a mean score of 34 mm out of 100 mm for overall liking (Table 3). However, across all 5 sensory attributes, the standard deviations of the paired differences were large (mean difference < 1.0, SD 15 to 21).

The Nothing Else bar had meaningfully lower scores compared with all four commercial snack bars across all 5 sensory attributes for both blind and informed tests with the 64 subjects (Table 6). The four commercial bars were rated by the participants in the same order of liking as the value of commercial sales (Table 5). The rating scores of Brand 1 were similar to that of Brand 2, but were meaningfully different to Brand 3 and Brand 4, across all 5 sensory attributes for both blind and informed tests (Table 6).

In the blind test, the Nothing Else bar was consistently and significantly ($p < 0.0001$) the least overall liked of all other bars. Brand 1 was overall liked more than all the other bars. Brand 2 was liked more than both of Brand 3 and Brand 4. There was however no difference in overall liking between Brand 3 and Brand 4. The Nothing Else bar was rated lower for taste than all other brands except for Brand 4.

After the packaging and branding for the bars were presented alongside the samples for testing in the informed test, the overall liking of the Nothing Else bar remained the lowest but increased by 5 percentage points from 34 to 39, showing a 14% improvement ($p = 0.023$) compared to the blind test. The taste score of the Nothing Else bar increased by 4.6 percentage points from 32.2 to 36.8% ($p = 0.042$). However, overall liking and taste scores for all the other bars did not change with packaging and brand knowledge.

Table 6. Sensory attribute ratings obtained from blind and informed consumer tests (n = 64), comparing the Nothing Else bar with four commercial products

Product / Attribute (mm)	NE*	B1	B2	B3	B4	
	Mean (SE)					‡p value
Blind						
Overall liking	34.3 (2.52)	73.0[a] (2.07)	62.1[a,b] (2.56)	52.2[a,b,,c] (2.93)	49.6[a,c] (2.77)	< 0.0001
Colour	38.2 (2.36)	73.6[a] (1.86)	63.1[a,b] (2.47)	46.3[a,b,c] (2.60)	47.8[a,c] (2.59)	< 0.0001
Taste	32.2 (2.49)	72.6[a] (2.09)	61.7[a,b] (2.80)	52.8[a,b,c] (3.22)	49.0[a,c] (3.12)	< 0.0001
Flavour	33.6 (2.78)	73.3[a] (2.06)	64.1[a,b] (2.70)	54.3[a,b,c] (3.10)	49.8[a,c] (3.13)	< 0.0001
Texture	33.8 (2.62)	70.8[a] (2.06)	64.1[a,b] (2.79)	51.3[a,b,c] (2.99)	50.0[a,c] (3.32)	< 0.0001
Informed						
Overall liking	39.0[†] (2.89)	71.0[a] (2.25)	60.0[a,b] (2.62)	52.5[a,b,c] (2.79)	52.0[a,c] (2.97)	< 0.0001
Colour	38.9 (3.01)	71.1[a] (2.23)	60.1[a,b] (2.62)	52.5[a,b,c] (2.79)	48.5[a,c] (2.66)	< 0.0001
Taste	36.8[†] (2.87)	70.9[a] (2.25)	59.6[a,b] (2.80)	52.8[a,b,c] (2.88)	49.5[a,c] (3.12)	< 0.0001
Flavour	37.0 (2.93)	72.5[a] (2.00)	60.2[a,b] (2.74)	53.4[a,b,c] (2.83)	50.3[a,c] (3.17)	< 0.0001
Texture	35.3 (2.85)	71.2[a] (2.18)	61.1[a,b] (2.73)	50.4[a,b,c] (3.01)	48.3[a,c] (3.36)	< 0.0001

NE, Nothing Else bar; B1 to B4, four commercial products; * In blind test, the NE values are the mean values of the replicate tests; ‡ ANOVA. Within the same row, [a] Mean value was significantly different to NE ($p < 0.05$); [b] Mean value was significantly different to B1 ($p < 0.05$); [c] Mean value was significantly different to B2 ($p < 0.05$).
†Different to blind test (p = 0.023, 0.042 for overall liking, taste, respectively).

When participants were asked to rank the five bars on healthiness, taste, naturalness, and purchase intent provided that prices were the same for all brands, Brand 1 was ranked the highest for both taste and purchase intent, while the Nothing Else bar was ranked the lowest (Table 7). Conversely the Nothing Else bar was ranked the highest for both naturalness and healthiness while Brand 1 was rated the lowest. The healthiness and naturalness rank sum total of the Nothing Else and Brand 4 were similar, and were significantly higher than those of the top three brands (B1, B2 and B3). When taste and purchase intent scores were compared, the rank sum total for Brand 1 was much higher than that for all other bars which were not different to each other.

Of the perceptions of importance of healthiness, taste and naturalness to consumers, taste was considered the most important, followed by healthiness, and then naturalness. However, there was no meaningful difference in importance of these three perceptions when the mean rankings were compared (3.9, 3.6 and 3.3, respectively).

Table 7. Rank sum total of healthiness, taste, naturalness, and purchase intent for five products from informed test (n = 64)

Product Perception	NE	B1	B2	B3	B4
Taste	161	251[a]	197	188	168
Healthiness	242	136[a]	142[a]	191[a]	234
Naturalness	253	137[a]	146[a]	185[a]	208
Purchase intent	166	222[a]	181	182	178

NE, Nothing Else; B1 to B4, four commercial products. Each perception was ranked from 1 (lowest) to 5 (highest). Within the same row, [a]Rank sum total was significantly different to others at $p < 0.05$ (Friedman test post hoc).

There were no meaningful differences based on age, gender and ethnicity of participants on either the blind or the informed test. However, when the tests of between-subjects effects were performed, differences were found (Table 8). The informed overall liking scores increased significantly with the older age group (p = 0.019), the male participants (p = 0.014), and non-Asian ethnic group (p = 0.011), in comparison with blind overall liking scores.

Of the perceptions of importance of healthiness, taste and naturalness to consumers, taste was considered more important than healthiness and naturalness for all age, gender, and ethnic groups.

Table 8. The effects of impact factors (age, gender and ethnicity) with 64 participants on overall liking scores of the Nothing Else bar in blind and informed tests

Characteristics	Overall liking (mm) Mean (SE)		p value
	Blind	Informed	
20 to 29 yrs	35.1 (3.18)	38.6 (3.64)	0.524
≥ 30 yrs	33.7 (4.25)	39.7 (4.87)	0.019
Men	30.3 (4.11)	37.3 (4.82)	0.014
Women	37.0 (3.14)	39.9 (3.64)	0.305
Asian	31.9 (3.26)	33.9 (3.65)	0.127
Non-Asian	38.5 (3.94)	46.4 (4.41)	0.011

Discussion

The Nothing Else snack prototype was least overall liked in comparison to the four commercial snack products, which was not surprising in view of its nutritional profile that was markedly different from the other bars, particularly in fibre content. Also the prototype was developed with low sugar and low fat contents to achieve a good

nutrient profiling score (FSANZ, 2012). Both sugar and fat are perceived as mouthfeel enhancers and flavour carriers and were high in the top three commercial bars. Brand 1 had the highest fat content (31.6g per 100g) compared to all other samples and Brand 3 had the highest sugar content (35.8g per 100g). The Nothing Else bar had less fat content (17g per 100g) and the least sugar content (20g per 100g, Table 9). Sugar and fat are known to influence consumers' acceptance and liking of a food product. Drewnowski (1989) demonstrated that consumers have developed sensory preferences for fat and sugar compared to other macronutrients both in their adolescence and adult life. Studies on ice cream also revealed that higher sugar and fat contents were correlated with consumers' acceptance (Guinard et al., 1997; Guinard, Zoumas-Morse, Panyam, & Kilara, 1996).

Branding and packaging of a food has an influential effect on consumer perception and has become an increasingly important factor in the food marketing system. Consumer trust and loyalty enhance consumer perceived value of a food product (Kapferer, 2004). However, which part of brand generates consumers' beliefs is not fully clear (Fernqvist & Ekelund, 2014). While healthiness is important, the taste of a food still remains a higher priority for consumers: consumers purchase intent is mainly influenced by taste and price. For health conscious consumers, nutrition and health claims have positive effects on the hedonic rating (Carillo, Varela, & Fiszman, 2012; Villegas, Carbonell, & Costell, 2008). In general, older consumers are more concerned about health than younger consumers (Roininen et al., 1999). Azzurra and Paola (2009) reported that mature people aged ≥ 35 years with higher level of education were particularly interested in health-related features of nutrition and foods. However in some studies, no association between health interest and consciousness and the hedonic ratings has been demonstrated (Fernqvist & Ekelund, 2014). Although interindividual variation in responses was high, there is some evidence that age and ethnicity of

participants influenced liking in this study. European and older participants liked the Nothing Else prototype more than Asian and younger participants.

The findings of this study illustrate the relative effects of branding and nutrition information on informed liking of the Nothing Else snack prototype. In the present study, the presence of branding did not improve the ratings of consumer liking for the four commercial snack products. There is insufficient evidence that branding of the commercial products had positive effects on liking where the overt listing, front-of pack, of all the ingredients on and health related information were associated with improved overall liking of the Nothing Else bar. The Nothing Else bar uses eight ingredients that are perceived as natural. Furthermore, it presented the general health parameters such as a low glycaemic index, a good fibre content, and a low sodium content (D. Brown et al., 2015).

The main limitation of the current relatively small study was that the design of this analysis was unbalanced by age and ethnic groups. Furthermore, the participants were a convenience sample and not representative of the population. Two thirds of the participants were relatively young, aged 20 to 29 years. Also almost two thirds of the study population were Asian. A comparison between different age groups found that the older age group (≥ 30 years) scored the sensory attributes of the Nothing Else bar higher and the most popular brand lower than that of the younger age group (20 to 29 years-data not shown). In addition, ‘muesli-style’ snack bars are not common snacks for Asian people who tended to rate the bars lower than Europeans. We propose that this might be due to food neophobia (unfamiliarity to food) of muesli and oat-based products among the Asian population. A study undertaken by Chung et al. (2012) demonstrated the differences in liking for Korean-style salad dressings and beverages between USA and Korean consumers living in North American in relation to context and cultural factors. They concluded that non-Korean consumers showed food neophobia contributing to the

disliking of Korean style salad dressing. Furthermore, the Nothing Else brand was new to most participants but familiarity of participants with the other established brands could have affected the scores of the informed test. Moreover, there might be potential unconscious bias on the part of AUT students towards an AUT-produced snack bar under the Nothing Else label because this is used for water and nuts also sold on campus. Therefore, sensory trial participants should be purposively selected in a more rigorous way. Future work is required to understand the magnitude of the effects of branding in the target group of consumers.

The hypothesis that branding and health information would improve consumer liking was confirmed in this study. Although the mean liking score of each sensory attribute of the Nothing Else bar was different than that of the four commercial products, there was a meaningful improvement in consumer overall liking of the Nothing Else snack prototype when branding and nutrition information were associated with the product. Future trials need to look at intraindividual variability in response to the effect of repeated exposure to a food as a one-off taste trial does not predict how consumers may adapt and like a product more with repeated exposure (Stein, Nagai, Nakagawa, & Beauchamp, 2003), as shown in our sales trial (D. Brown et al., 2015).

Conclusion

This study has produced evidence that a healthier snack bar with clear front-of-pack labelling listing all the ingredients ‘Nothing Else’ was overall liked more than in the blind condition when the packaging was shown to consumers. This was not the case for other four commercial snack product. Our findings confirmed that the branding and health related nutrition information could improve consumer liking and brand perception particularly if backed by marketing.

Table 9. Nutritional information panel of the test products per 100g

Food	Energy (kJ)	Protein (g)	Fat total (g)	Saturated fat (g)	CHO (g)	Sugar (g)	Fibre (g)
Nothing Else*	1544	11.6	17.1	2.1	44.9	20.3	8.2
Brand 1	2160	14.2	31.6	6.7	40.2	23.8	5.5
Brand 2	1880	10.3	21.3	9.0	55.7	24.4	5.0
Brand 3	1610	6.5	14.1	7.4	60.1	35.8	4.8
Brand 4	1430	8.9	1.3	0.3	68	21.4	9.0

* Derived from food composition tables using FoodWorks version 7 (Xyris Pty Ltd., Australia).

Chapter 5

Study Three: Glycaemic and Satiety Effects

Snack Bar Composition and their Acute Glycaemic and Satiety Effects

Abstract Maintaining blood glucose within homeostatic limits and eating foods that suppress hunger and promote satiety have beneficial impacts for health. This study investigated the glycaemic response and satiety effects of a serving size of a healthier snack bar, branded Nothing Else that met the required nutrient profiling score criteria for a health claim, in comparison to two top-selling commercial snack bars. In an experimental study, 24 participants aged ≥ 50 years were recruited. On three different days, blood glucose concentration was measured twice at baseline and 15, 30, 45, 60, 90 and 120 minutes after consumption of a serving size of each bar. Satiety effects were self-reported hunger, fullness, desire to eat, and amount could eat ratings on visual analogue scales. The incremental area under the blood glucose response curve (iAUC) over two hours for the Nothing Else bar was 30% lower than commercial Bar 2 ($p < 0.001$). At 45 minutes after eating, the Nothing Else bar induced the highest fullness rating and lowest hunger rating among the three snack bars. At two hours, fullness induced by the Nothing Else bar was twice that of Bar 2 ($p = 0.019$), but not different to Bar 1 ($p = 0.212$). The Nothing Else snack bar developed using the nutrient profiling scheme as a guideline, with its high protein and dietary fibre contents, had a lower glycaemic impact and induced a higher subjective satiety than the two commercial snack bars of equal weight.

Keywords: macronutrient, nutrient profiling, glycaemic response, hunger, satiety

Introduction

Dietary exposure over a life time contributes greatly to the risk of chronic diseases such as obesity and diabetes (World Health Organisation, 2003). Maintaining blood glucose within homeostatic limits and eating foods that suppress hunger and promote satiety have beneficial impacts for health and prevention of type 2 diabetes (Bell & Rolls, 2001; Reynolds et al., 2009; Solomon et al., 2010). The challenge is that many commercial products, such as snack bars, perceived as healthy by the consumer, do not meet the required nutrient profiling score (NPS) criteria for health claims (< 4) (FSANZ, 2015). Snack foods contribute to more than 20% of the daily energy intake in many Western countries (Bilman et al., 2010; Furchner-Evanson et al., 2010). In 2014, the sales value of snack bars in New Zealand was NZ $132 million with muesli bars accounting for NZ $71 million, forecast to retain the same sales value by 2019 (Euromonitor International, 2015). However, snacking behaviour in relation to heath properties of snack foods such as glycaemic impact and satiety has not been well studied (Bilman et al., 2010). There are very few snack products which are made of all natural ingredients in the New Zealand market. Further, there are very few studies available on snack bar macronutrient composition in relation to glycaemia and satiety effects.

Reformulation to improve nutrition profile and front-of-pack food labels is promoted by governments to improve public health nutrition (Friel, Hattersley, Ford, & O'Rourke, 2015), and there is evidence that government-led food reformulation initiatives improve the quality of food supply, for example to reduce salt intake (Webster, Dunford, & Neal, 2010). However, to date, most actions have involved voluntary industry commitments. There has been a call for high value nutrition products but the focus has been on export and sales rather than improvement in public health.

This study aimed to investigate the glycaemic response and satiety effects over

two hours on consumption of an eight ingredient snack bar, branded Nothing Else, in comparison with two top-selling commercial snack bars at each serving size on three different days. Moreover, this study aimed to explore the association between satiety and blood glucose concentration, and the association between macronutrient composition (e.g. protein, fibre, sugar content) and the physiological effects of a snack product.

Materials and Methods

Number of participants and participants

Health claims on reduction in postprandial glycaemic response requires that a test food has a statistically significant decrease (minimum 20%) in incremental area under the blood glucose response curve (iAUC) in comparison to the reference food (Health Canada, 2013). The mean coefficient of variations (CVs) for testing glucose from literature are in the range of 20-30% (Wolever et al., 2008). Therefore, this experimental study with a predicted minimum 20% decrease in iAUC with a CV of 25%, would require 26 subjects to detect a 20% difference in glucose iAUC. This scenario would have 80% power and an alpha of 0.05.

People aged ≥ 50 years were recruited to the study because older people are more likely to be insulin resistant and benefit from a lower glycaemic load diet. People were not eligible if they had been diagnosed with diabetes mellitus, cardiovascular disease, diseases of the digestive system, or were receiving medication that might affect glucose metabolism. Ethics approval was provided by Auckland University of Technology Ethics Committee (Reference no. 14/342). Participants were provided with written information and the opportunity to ask questions before signing written consent to participate.

Samples and sample preparation

The Nothing Else bar, which met the NPS criteria for a health claim (FSANZ, 2015), was developed in partnership with a food manufacturer. The glycaemic index (GI) of the Nothing Else bar was measured with 10 healthy subjects (International Organisation for Standardisation, 2010), and was low (52). Two commercial snack bars were selected from New Zealand top-selling brands (Euromonitor International, 2015). From the preliminary sensory study (Yan et al., 2015), Bar 1 had the highest overall liking score, Bar 2 had similar ingredients and similar liking score to the Nothing Else bar. The Nothing Else bar was prepared in the kitchen in School of Hospitality, Auckland University of Technology. Two commercial snack bars were purchased from local supermarket in Auckland, New Zealand.

Each snack bar was provided to participants at the serving size on a plate without packaging to reduce participant bias. The nutritional information and ingredients of three snack bars are shown in Table 10.

Table 10. Nutritional information and ingredients of three snack bars

Product	Serving size (g)	Energy (kJ)	Protein (g)	Fat total (g)	Saturated fat (g)	CHO (g)	Sugars (g)	Fibre (g)	NPS
Nothing Else†	40	600	4.5	6.8	0.8	17.9	8.1	3.3	-1
Bar 1	35	755	5	11.1	2.4	14.1	8.3	1.9	11
Bar 2	40	652	2.5	5.6	3.5	22.6	15.1	2.2	15

CHO: carbohydrate

NPS: nutrient profiling score, derived from nutrient profiling model (FSANZ, 2015). A food with a NPS > 4 is unable to make health claims.

†Derived from food composition tables (FoodWorks version 7, Xyris Pty Ltd., Australia).

Nothing Else bar ingredients‡: Rolled oats, almonds, dates, egg white, oat bran, honey, sunflower oil, cinnamon. **Bar 1 ingredients:** Peanuts, almonds, dates, sultanas, milk powder, cocoa powder, vegetable oil, soy lecithin, citric acid, brown sugar, puffed wheat, glucose, sugar, honey, sunflower seeds, glycerol, maltodextrin. **Bar 2 ingredients:** Sultanas, rolled oats, wheat flour, butter, milk powder, desiccated coconut, preservative, raw sugar, honey, sugar, oat bran, whole egg powder, raising agent, flavour, salt.

‡By descending order of ongoing weight.

Experimental protocol

Blood glucose concentration was measured following the international standard method ISO 26642:2010(E) (International Organisation for Standardisation, 2010). Participants were asked to attend the laboratory on three mornings after a 10-12 hour overnight fast and standardisation of physical activity and the last meal of the previous day. Capillary blood samples were collected and analysed (HemoCue Glucose 201^{+}, HemoCue AB, Ängelholm, Sweden) from finger pricking twice at baseline, and at 15, 30, 45, 60, 90 and 120 minutes after the start of the ingestion of a snack bar offered in a random order. Participants were asked to remain seated during the course of the tests.

After each blood sample subjective satiety effects on hunger, fullness, desire to eat, and amount could eat were self-reported on 100 mm visual analogue scales verbally anchored e.g. “not at all full” and “extremely full” at the endpoints (Flint, Raben, Blundell, & Astrup, 2000; Holt, Brand-Miller, & Stitt, 2001).

Statistical analysis

Average fasting, postprandial blood glucose concentrations and satiety responses were plotted against time for each test food. Data were presented as mean ± SD. The glucose iAUC (mmol min L^{-1}) (i.e. the area above the baseline fasting glucose) was determined geometrically by applying the trapezoid rule (International Organisation for Standardisation, 2010). The changes in the satiety response (mm) were calculated. The iAUC and change of satiety scores of the Nothing Else bar were compared separately with those of two commercial bars by repeated measures ANOVA with Bonferroni’s correction and post hoc paired *t*-test to determine if a statistical difference existed at $p < 0.05$. Satiety scores were compared with the iAUC to explore the association between satiety and blood glucose concentration using Pearson’s linear correlation coefficient. The iAUC values of the three snack bars were compared in relation to the nutrients of

each snack bar to explore the association between macronutrient composition and the physiological effects. Statistical analysis was performed using SPSS version 22, 2013 (IBM Corporation, NY, USA).

Results

In 24 healthy subjects (12 men, 12 women; aged 50-71 years, 14 overweight/ obese, 6 Asian, 18 European; fasting glucose 4.3-5.9 mmol L^{-1}), intra-individual mean fasting blood glucose concentrations were not different by day of testing (mean difference 0.1 ± 0.3 mmol L^{-1}, $p = 0.565$) (Figure 8). Thirty minutes after consumption, the rise in blood glucose for the Nothing Else bar was less than that for Bars 1 and 2 (6.1 ± 0.7, 6.7 ± 0.9 and 7.1 ± 0.9 mmol L^{-1}; respectively). This difference was also seen at 45 minutes. Over two hours, the iAUC for the Nothing Else bar (89.9 ± 7.7 mmol min L^{-1}) was not different to Bar 1 (87.8 ± 7.1 mmol min L^{-1}), but was 30% lower than that for Bar 2 (122.6 ± 8.7 mmol min L^{-1}, $p < 0.001$). The rise of blood glucose over 45 minutes in response to the Nothing Else bar appeared to be slower and lower than that for the other two bars (Figure 8). With five participants, the glycaemic response to Bar 1 did not return to baseline within two hours and stayed elevated for three hours. The individual glycaemic responses to the three snack bars are presented in Appendix G.

Participants recorded that the Nothing Else bar produced the highest fullness rating and the lowest hunger rating among the three snack bars at 30 and 45 minutes after eating. Bar 2 was associated with the higher hunger ratings and lower fullness ratings (Figure 9). At two hours, the increase of fullness induced by the Nothing Else bar was twice that of Bar 2 ($p = 0.019$), but not different to Bar 1 ($p = 0.212$). At two hours following consumption hunger rating for the Nothing Else bar was not different to baseline but that for Bar 1 and Bar 2 were significantly raised above baseline (6 and 8 mm, $p = 0.013$ and 0.004, respectively) and hunger had been elevated above baseline from 60 minutes (Figure 9). A similar pattern was seen for desire to eat, whereas the

perception of amount that could be eaten after consuming the Nothing Else bar was less than the baseline of 0 (-6.6 ± 1.9 mm, 95%CI [-11.2, -1.9]), and also less than that for Bar 1 (2.0 ± 2.1 mm, [-3.1, 7.0]) and Bar 2 (3.0 ± 1.7 mm, [-1.0, 7.1]) (Figure 9).

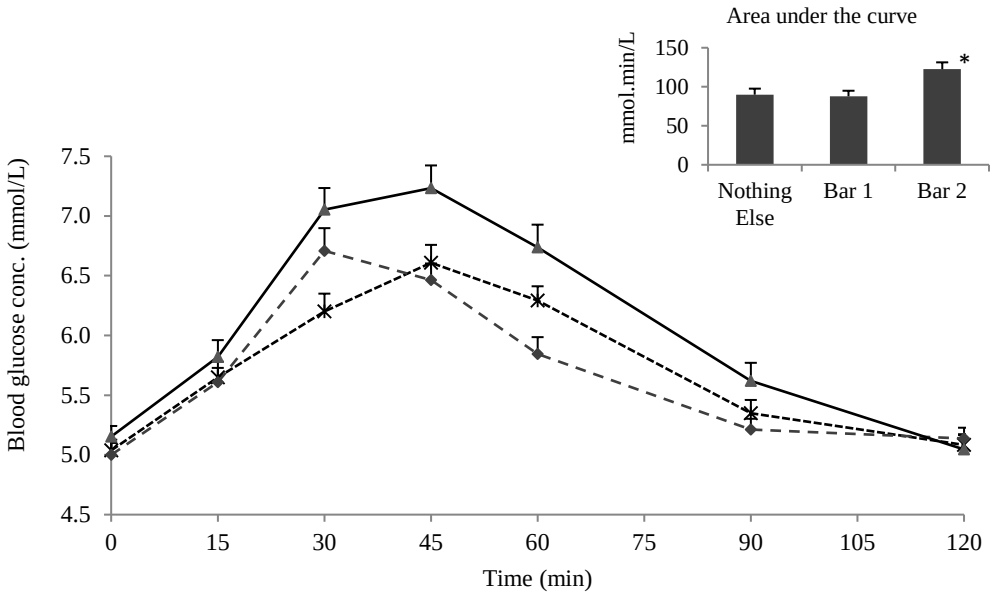


Figure 8. Mean glycaemic responses and incremental areas under the curve elicited by the Nothing Else bar, Bar 1, and Bar 2 in 24 healthy subjects aged ≥ 50 years. Error bars are standard errors. Stars - Nothing Else; Diamonds - Bar 1; Triangles - Bar 2. *Different to the Nothing Else bar and Bar 1 ($p < 0.001$).

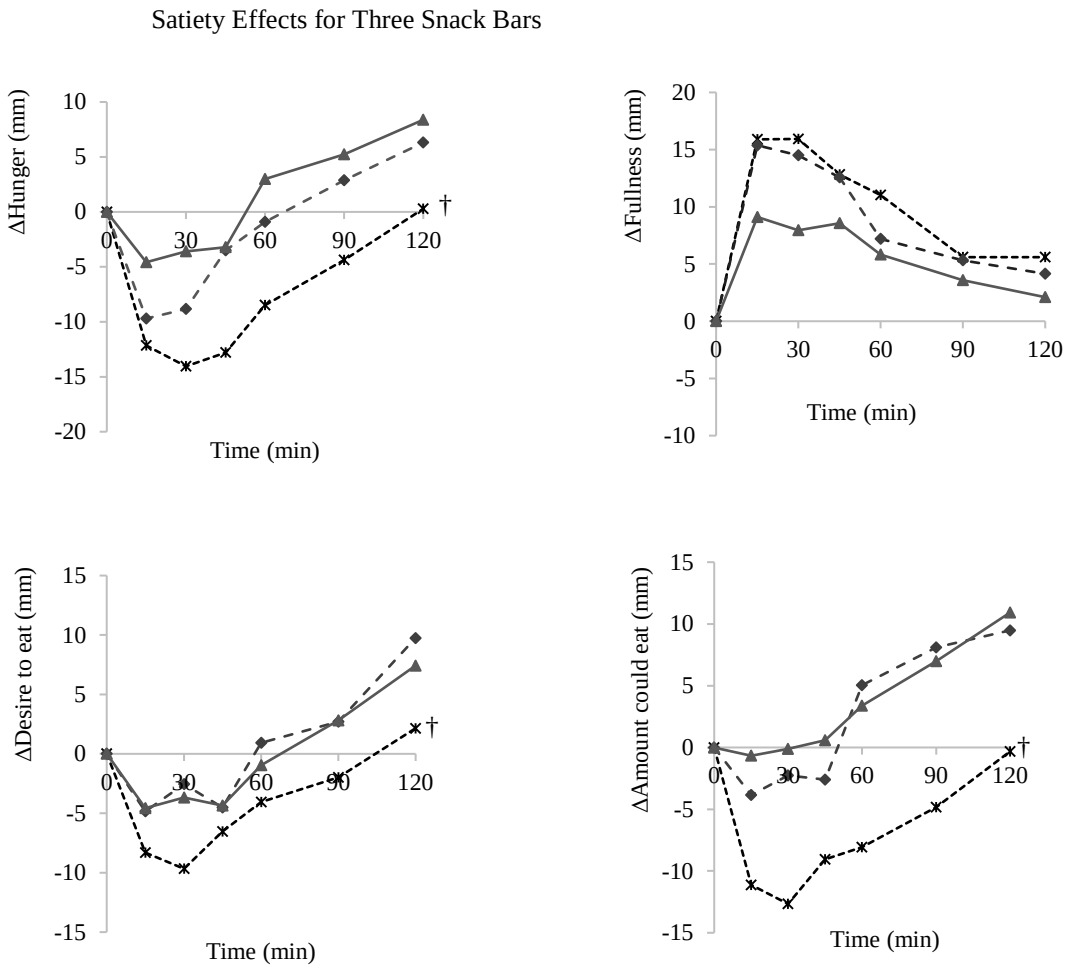


Figure 9. Mean changes (Δ) in self-reported hunger, fullness, desire to eat, and amount could eat ratings obtained on 100 mm visual analogue scales by 24 participants on three test days. Stars - Nothing Else; Diamonds - Bar 1; Triangles - Bar 2. †Different to Bar 1 and Bar 2 ($p < 0.05$).

Fullness and hunger ratings were not strongly correlated with the blood glucose concentrations in the present study either at 30 minutes or at 45 minutes where higher blood glucose concentrations were observed (Table 11). When all paired measurements of fullness and blood glucose concentrations over 120 minutes were considered positive correlations were observed for the three bars (Nothing Else bar, Bar 1 and Bar 2; r = 0.75, 0.79, 0.77, respectively); and hunger ratings were negatively correlated with blood glucose concentrations (r = - 0.85, - 0.67, - 0.57, respectively).

Protein, fat and fibre (g/serving) were negatively correlated to iAUC and were positively correlated to fullness. Conversely carbohydrates and sugar were positively correlated to iAUC and negatively correlated to fullness. The correlation between sugar content and iAUC was significant ($r = 0.997$, $p = 0.048$).

Discussion

One 40 g serving of the Nothing Else bar elicited lower glycaemic and higher satiety responses than 35 g and 40 g servings of two commercial snack bars. Furthermore, the Nothing Else bar had the most favourable nutrition profile in relation to fibre, protein and saturated fat. Therefore, the Nothing Else bar could be judged as the most beneficial from the point of view of glycaemic response, satiation and reducing hunger.

To our knowledge, this is the first investigation that has examined the relationships between the nutrition profile, glycaemic response, and satiety for a specific product. It is known that protein is more satiating than carbohydrates or fat (Anderson & Moore, 2004; Astrup, 2006; Westerterp-Plantenga, 2003). Williams et al. (2006) reported that consumption of a high protein, high fibre snack improved short term glucose profile and reduced subsequent food intake compared to a high fat snack. However, the nutrient profiles of the test snacks were undeclared. The Nothing Else bar was developed by selecting wholesome ingredients that in combination would meet the nutrient profiling score criterion for a health claim (FSANZ, 2015), and with structures, e.g., that would help to lower glycaemic impact (GI = 52, unpublished). To our knowledge, the GI values of the two commercial bars have not been tested. The suggested origin for the occurrence of the favourable glycaemic and satiety responses is the nutrient profile and physical structure of the snack bar, which is dependent on the quantity and properties of the ingredients. Each is considered in turn.

Nutrient profile and glycaemic and satiating properties

The physical properties of food affect physiological processes and in turn are correlated to blood glucose response and sensation of satiety (Norden, 2009). All the snack bars contained at least five grams of fat from various sources. Fat content in a food may delay gastric emptying and affect insulin secretion resulting in a lower glycaemic response (D. J. Jenkins et al., 1981; Welch, Bruce, Hill, & Read, 1987), however, a high fat content in a food, in particular saturated fat, could contribute to health problems (de Souza et al., 2015), and certainly makes the food more energy dense. Moreover, although fat reduces the initial rise of blood glucose after eating, it also prolongs elevated blood glucose concentration and a second glucose peak is produced (Owen & Wolever, 2003). This was shown in the present study with Bar 1. Despite of the similar protein content to that of the Nothing Else bar, Bar 1 induced the highest hunger rating among the three snack bars, which may be explained as fat resulting in a low satiation effect compared to protein and carbohydrates (Bell & Rolls, 2001; Blundell & Macdiarmid, 1997). High fat foods may also stimulate excessive consumption, because of the palatability (de Castro, Bellisle, & Dalix, 2000; de Castro, Bellisle, Dalix, & Pearcey, 2000; Drewnowski, 1997).

The higher carbohydrate and sugar contents in Bar 2 were associated with a higher iAUC than that of the other two snack bars. High protein food has higher specific satiety than low protein food (Raben et al., 2003; Veldhorst et al., 2008). Therefore the low protein content in Bar 2 may explain why this bar was rated the lowest for fullness. It is known that, in the short term, whole foods with low energy density increase satiety, decrease the feeling of hunger and reduce energy intake (Bell & Rolls, 2001). Even though the correlations between glycaemic response, satiety, and macronutrients such as protein, fat, fibre from the current study were trivial, there was nonetheless a trend seen for the quantity of those nutrients to be associated with the responses.

Effect of ingredients

Of the eight ingredients of the Nothing Else bar, rolled oats and almonds were in the largest proportion, more than 55% by weight. Oats are contemporarily considered a healthy food with many already known health benefits, such as modulation of glucose metabolism and reduction of hunger (Slavin, 2004). In particular, oat bran reduces postprandial glycaemic and insulinemic responses (Tapola et al., 2005). Almonds offer healthy fats and give pleasant aroma and texture, and are rich in protein. Both oats and almonds were rich in fibre which was associated with low glycaemic impact and high satiety effect (Kendall, Esfahani, & Jenkins, 2010). In addition, *in vitro* and *in vivo* animal studies have demonstrated the blood sugar regulation properties of cinnamon (Akilen et al., 2012). Research has suggested that consumption of cinnamon is associated with lowering glycated hemoglobin (HbA1c) and fasting plasma glucose, low density lipoprotein cholesterol, and triglyceride levels (Akilen et al., 2012; Blevins et al., 2007).

In contrast to the Nothing Else bar, both the commercial bars have far more ingredients (≥ 15, Table 9). Even though some ingredients in the two commercial bars were same to that of the Nothing Else bar, for example, almonds (7% by weight) in Bar 1, and oats and oat bran (17% by weight) in Bar 2, the proportions of these ingredients were small. Peanuts were in the largest proportion in Bar 1, 42% by weight. The peanuts, almonds and vegetable oil in Bar 1 contributed to the high fat content and high energy density of this bar. Sultanas, sugar and honey in Bar 2 represented the highest sugar content which contributed to the highest glycaemic impact. Moreover, the two commercial bars contain artificial flavor and preservatives, which rationally or irrationally would not meet the growing consumer interest for perceived natural and healthy foods (Pollan, 2008).

Strengths and limitations

Over the past decades, there has been a debate that whether GI is a likely predictor of satiety and hunger. Studies have shown that low GI foods are associated with an increase of satiety, a delay in the return of appetite, and a reduction of consumption in the short term (Niwano et al., 2009). The results for the Nothing Else bar support this outcome. However, the GI values of the two commercial bars were unknown and the relationship has not been measured.

The present study showed that the Nothing Else bar had a 30% reduction in postprandial glycaemic response compared to another bar at equal weight which added to the evidence for a health claim for the bar. The present report is one stage of providing an evidence-base that shows the relationships between the nutrient profile, glycaemic response, and satiety for a specific product. Unlike GI which uses a standard amount of carbohydrate, the design of this study was more similar to a natural setting in which snack bars were consumed at a packed serving size.

This was a small study where participants self-identified as healthy individuals without diabetes although more than half were overweight and therefore could be insulin resistant. The study is further limited because insulin resistance was not measured and the time of measurement of the effects was limited to two hours following consumption of a bar unaccompanied by other foods such as milky tea or coffee. Future work is required to investigate the medium to long term glycaemic impact on consumption of the Nothing Else bar, and whether food products of this type are acceptable as part of dietary pattern.

Conclusion

The Nothing Else snack bar, with its high protein and dietary fibre content, had a lower glycaemic impact and induced a higher subjective satiety than two commercial snack products of equal weight in the short term. A wider availability of food with nutrition and verifiable health claims could help consumers to make healthier choices. This was achieved by evidence-based food reformulation to produce a food product which was low in refined starch, high in protein, dietary fibre, and fruits and nuts, and used the nutrient profiling scheme as a guideline.

Table 11. Correlation between individual's fullness ratings and blood glucose concentrations at 30 and 45 minutes after consuming the test snack bars, $n = 24$

Product	30 min after eating			45 min after eating		
	r	*p* value	95% CI	*r*	*p* value	95% CI
Nothing Else	0.388	0.061	(24.5, 44.8)	0.153	0.476	(22.3, 40.8)
Bar 1	0.115	0.591	(21.1, 41.3)	0.200	0.349	(18.9, 39.6)
Bar 2	0.421*	0.040	(20.2, 37.5)	0.282	0.183	(20.1, 38.8)

Pearson correlation (2-tailed). *Correlation was significant at $p < 0.05$.

Chapter 6

Study Four: Intervention Study

Effects of a Healthier Snack on Snacking Habits and HbA1c: A 6-week Intervention Study

Abstract Dietary behaviour modification may change eating habits and reduce the impact of poor nutrition. This study aimed to evaluate the effects of daily consumption of a healthier snack bar on snacking habits and HbA1c within a 6-week intervention. Twenty-eight participants were randomly allocated to two groups to either consume the bar as the main snack for 6 weeks (n = 14) or receipt of the bars was delayed for 6 weeks (n = 14) following a stepped wedge design. All participants had HbA1c concentrations measured at weeks -1, 0, 4, 6, 10, and 12. A short dietary habits questionnaire was self-completed at weeks 0, 6, and 12. Participants consumed the bars they received instead of other snacks and found the healthier snack was acceptable as part of their daily dietary pattern. Over the 12 weeks, there was a significant reduction in intake of biscuits, cakes and pies (~2 servings/week, $p < 0.05$) in both groups. Fruit juice intake was reduced (~1 serving/week, p = 0.029) in the first group. Twenty participants (71.4%) experienced a decrease (n = 15) or no change (n = 5) in HbA1c (range 0-4 mmol/mol); while eight participants experienced an increase in HbA1c (range 0.5-2.5 mmol/mol). There was high compliance with the healthier snack intervention and a trend toward a favourable effect on glucose homeostasis. Habitual snacking behaviour has the potential to be improved through changes in the food supply and in the longer term may reduce the impact of poor nutrition on public health.

Keywords: dietary behaviour: glycaemic impact: HbA1c: intervention: snacking

Introduction

Dietary pattern and nutrition are modifiable factors in relation to the risk of chronic diseases such as obesity and diabetes mellitus (Hawkes et al., 2015). Thus, the incidence and impact of poor nutrition can be reduced by dietary behaviour modification and a systems approach of changes in the food supply and food labelling (England, Thompson, Jago, Cooper, & Andrews, 2014; McGeoch et al., 2011).

Snacking is a typical eating behaviour and may be associated with poor nutrition because generally snack foods are energy and refined carbohydrate dense and nutrient poor (Bellisle, 2014; De Vet, Stok, De Wit, & De Ridder, 2015; Feeley, Musenge, Pettifor, & Norris, 2012). An example is 'muesli-style' snack bars that are often regarded as being healthy, however, most commercial snack bars are high in added sugar and fat: energy dense and low in protein, fruits and dietary fibre (Yan et al., 2015). Snacking behaviour is habitual and is a dietary behaviour that has potential to be modified by changing the food environment (De Vet et al., 2015). In New Zealand, 55% of packaged food has been reported unhealthy based on nutrient profile systems (Ni Mhurchu et al., 2016). It has been shown that low glycaemic index (GI) foods and low glycaemic load (GL) diets may reduce metabolic risk factors including postprandial hyperglycaemia, insulin resistance and impaired haemostasis (Burton et al., 2011), and improve hemoglobin A1c (HbA1c) (Brand-Miller et al., 2003; Reynolds et al., 2009; Solomon et al., 2010). There has been a call for product reformulation and healthier foods in retail outlets and vending machines to meet the growing consumer needs (Hawkes et al., 2015; Siro et al., 2008).

The Nothing Else brand is a front of pack label that lists up to eight ingredients, all perceived as natural (D. Brown et al., 2015). A Nothing Else almonds and dates bar, its recipe met the nutrient profiling scoring criterion for a health claim (FSANZ, 2015), has been developed and the GI was low (52) (International Organisation for Standardisation,

2010). Our previous studies revealed that compared to two top selling commercial snack bars of equal weight, the consumption of the Nothing Else bar had a 30% reduction in incremental area under the blood glucose response curve (iAUC), and induced the highest fullness rating and lowest hunger rating over two hours (Yan, Parsons, Whalley, Kelleher, & Rush, 2017). However, it is unclear whether consumption of healthier snack foods of this type has long term effects on snacking habits and blood glucose control.

The present study aimed to investigate (1) compliance with and (2) the glycaemic impact of consumption of the Nothing Else bar over 6 weeks in a stepped wedge randomised trial. Stepped wedge randomised trials are particularly used for evaluations where an intervention is predicted to do more good than harm despite lack of evidence of effectiveness (Hussey & Hughes, 2007; Mdege, Man, Taylor, & Torgerson, 2011). Secondary objectives were to collect participants' perceptions of the new prototype bar and concomitant changes in habitual snack behaviour.

Materials and Methods

Participants

A total of thirty participants were recruited from professionals at a tertiary institute in Auckland. People were eligible if they usually ate snacks containing refined carbohydrate and particularly ate at least three to four snack bars a week, were ≥ 40 years of age; and were relatively sedentary (on the basis that they are more likely to be insulin resistant and benefit from a lower glycaemic load in their diet). They were also required to not be on any medication that would affect blood glucose concentration and could commit to the time requirements of the trial. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by Auckland University of Technology Ethics Committee (Reference no. 14/379). Participants were given full details of the study

protocol and the opportunity to ask questions. All participants signed a consent form prior to participation.

A power calculation was performed using the results of other experimental studies in GI, glycaemic control and HbA1c. Jimenez-Cruz, Bacardi-Gascon, Turnbull, Rosales-Garay, and Severino-Lugo (2003) and Rizkalla et al. (2004) reported a significant improvement of HbA1c after 4, 6 and up to 12 weeks consumption of low GI diets by people with diagnosed diabetes mellitus. The effective changes in HbA1c reported in the literature are in the range of 0.4-0.7% (5-7 mmol mol^{-1}). In the present study, to detect a change of 0.6% (6 mmol mol^{-1}) in HbA1c (equivalent to one diabetes medication) (American Diabetes Association, 2015; Horswell, Wascom, Cerise, Besse, & Johnson, 2008) using a two-step randomised trial, twenty-six participants would be sufficient to have > 80% power and an alpha of 0.05. Thirty participants would allow for a 15% dropout rate.

Snack preparation

The Nothing Else almonds and dates bars were prepared by AB Foods Ltd., Auckland, following the initial development of the recipe at Auckland University of Technology. The water activity of the bars was 0.68 that ensured shelf stability without preservatives. The nutrient profile of the snack bar is outlined in Table 12. The participants were provided with a colour copy of the front and back of pack labels of the Nothing Else bar as part of the informed consent process and to simulate the information they would receive if they bought a commercial bar.

Study design

This study was a stepped wedge trial in which thirty participants were assigned to two groups to receive the intervention using a stratified random design. Two steps were applied and time between steps was 6 weeks as determined by the power calculation

based on other studies. The first group (n = 15) started receiving the intervention in week 1. The second group (n = 15) started receiving the intervention in week 6. The stepped wedge design is more ethical and practical compared with parallel or crossover designs. In this approach, the crossover is in one-way only, from control to intervention, and does not require a wash out period. Participants are randomly allocated a time point to receive intervention. Participants receive intervention in a random order while all the participants are unable to start the trial at the same time, however by the end of the trial, all the participants receive the intervention (Hussey & Hughes, 2007; Mdege et al., 2011).

In the present study, participants were not asked to change their normal diet before receiving the intervention. In the 6-week intervention period, participants were asked to consume the Nothing Else bar each day as their main snack choice, and were instructed that they could still eat fresh fruits. Participants were supplied with enough snack bars each week to replace their usual snacks and asked to keep a snacking diary to record the numbers of the Nothing Else bars consumed as a measure of compliance, and time of consumption of the snack bar. Participants had opportunities to ask for more snack bars as needed.

Snacking habits were assessed with a short dietary habits questionnaire designed to collect information over the previous 6 weeks about the consumption of sweets; baked goods such as muesli bars, sweet biscuits, cakes, cookies, brownies, muffins, pies; fruit juice and sugary drinks; and high glycaemic impact/load foods such as white bread and rice. The questionnaire was adapted from a validated short food frequency questionnaire (Boniface, 2013), which was designed to measure sugar intake in Pacific Islanders living in South Auckland, New Zealand. The response options for the frequency of intake of specific foods and a specified amount of food were: less than once per month, less than once per week, 1, 2, 3-4, 5-6, 7 or more times per week, plus

2-3, 4-6 times per day for recording frequency greater than once per day. Data included intake of specific foods both at home and away from home. The physical activity levels at work (levels 1 to 4) and at leisure time (levels 1 to 5) were ranked using the two questions of Johansson and Westerterp (2008). The questionnaire was completed by each participant three times, at weeks 0, 6 and 12.

The HbA1c concentration was tested using capillary blood filled in a test cartridge (Axis-Shield, Oslo, Norway) then determined by an Afinion^{TM} hemoglobin A1c device (Axis-Shield, Oslo, Norway). The point-of-care measure has been reported as a rapid, accurate and precise method (Dixon-Woods, McNicol, & Martin, 2012; Wan Mohd Zin, Ahmad Kamil, Tuan Soh, Embong, & Wan Mohamud, 2013). For both groups, finger-prick HbA1c concentrations were tested at weeks -1, 0 (one week prior and immediately before random allocation) for baseline, then four more times at weeks 4, 6, 10, and 12. In total the duration of the trial was 13 weeks.

Data analysis

Statistical analyses were performed using SPSS, version 23, 2015 (IBM Corporation, New York, USA). Non-parametric data were presented as median and interquartile ranges and categorical as percentage of frequency. Continuous normally distributed data were summarised as means and standard deviations. Differences in non-parametric data within-group were determined by the related samples Wilcoxon signed rank test. Baseline HbA1c was calculated as the mean of measures at weeks -1 and 0. The between-group comparison of Hba1c was carried out using an independent *t* test. The effect of the intervention (started week 0 or week 6) on changes (Δ) in HbA1c within-group at weeks 6 and 12 (for intervention in first or second time period) over a 12-week time course were assessed using a repeated measures ANOVA with period as a cofactor. All statistical tests were two-tailed and a 5% significance level maintained throughout the analysis. Difference in proportions was assessed using one sample z test.

Compliance was assessed as the percentage of participants who consumed at least 5 bars a week for 6 consecutive weeks. Any changes in participant's eating behaviour were in descriptive terms.

Results

Twenty-eight healthy subjects (ten men, eighteen women; aged 44-71 years) completed the 13-week trial. Two participants withdrew in the first week: one could not receive the snack bar on a weekly basis and another could not attend the session for the second HbA1c measurement. Physical activity levels did not change across the intervention for both groups, the majority (> 64%) of participants reported low levels of physical activity at work and only a slight increase in physical activity at leisure time.

Twenty-six participants reported that they consumed between 5 and 14 bars a week in the intervention period (Table 13). Two participants had a week each of sickness and did not consume the Nothing Else bars that week. Overall 92% of the bars provided were consumed as directed.

Participants reported that in the 6 weeks prior to the trial, they consumed snacks on 3 to 7 days a week, with biscuits, cakes and pies the most frequently consumed snacks in addition to snack bars (Table 13). During the 6-week intervention period, participants in both groups consumed more snack bars ($p < 0.05$, Table 13) than during the control period. In both groups, consumption of the snack bar was associayted with a substantial reduction in intake if biscuits, cakes and pies (~ 2 servings/week, $p = 0.044$, 0.003 in group 1 and 2, respectively; Table 13). More than 60% of the participants did not consume biscuits or ate biscuits less than once per week during the intervention period (data not shown). The consumption of fruit juice was reduced (~ 1 serving/week, $p = 0.029$) in the first group but not in the second group. Furthermore, there was a tendency for white bread to be consumed less often but there was no change with the

frequency of rice consumption in both groups. From the self-report of daily snack consumption, all snack bars were eaten in the mid-morning and/or mid-afternoon, which are the typical tea break times in New Zealand.

For the baseline HbA1c tested twice a week apart, there was no difference in the mean value (means 36, 36 mmol mol^{-1}, 95%CI difference -0.4, 0.8, p = 0.449). The average of the preintervention measures was used as the baseline comparison (Table 14). There was no significant difference in HbA1c between two groups at week 6 (p = 0.673). There was no effect of period of treatment. Overall trivial to moderate decreases of HbA1c (Table 14) were observed in both groups after 6 weeks consumption of the Nothing Else snack bar, with not all participants experienced a decrease (Figure 10). Twenty participants experienced a decrease or no change in HbA1c (range 0-4 mmol mol^{-1}, five participants had no changes observed), while eight participants (four men, four women; five overweight; baseline HbA1c 36.4 ±1.19 mmol mol^{-1}) experienced an increase in HbA1c (range 0.5-2.5 mmol mol^{-1}, Figure 10).

Table 12. Nutritional profile of the Nothing Else almonds & dates bar

	Serving size 40 g
Energy (kJ)	600
Protein (g)	4.6
Fat (g)	6.8
Saturated fat (g)	0.8
Carbohydrate (g)	17.9
Sugars (g)	8.1
Dietary fibre (g)	3.3
Sodium (mg)	15
NPS	0

Ingredients: oats (43%), dates (19%), almonds (13%), oat bran, egg white, honey, sunflower oil, cinnamon.

NPS, nutrient profiling score (FSANZ, 2015).

The HbA1c of the participants in group 1 (n = 14) decreased in the first 6 weeks when receiving the intervention then increased slightly once the intervention finished, but were still less than baseline. The HbA1c of the participants in group 2 (n = 14) tended to decrease during the 6 weeks control period and continued decrease during the intervention period (Table 14). Only eight participants out of twenty-eight (28.6%) had an increase in HbA1c after 6 weeks of consumption of the bars. Compared with the null hypothesis of 50% increasing and 50% decreasing, the intervention was more likely to decrease or have no change in HbA1c of an individual (p = 0.024, 95%CI 13.2, 48.7%, z test for proportions).

Table 13. Snacks and high glycaemic impact foods consumed in the control and intervention periods

Food	Group 1 (n = 14)			Group 2 (n = 14)		
	Baseline (-1, 0 wk)	Intervention	Postintervention	Baseline (-1, 0 wk)	Control	Intervention
		6 wk	12 wk		6 wk	12 wk
Days of snacking/week	4 (3, 6)	7 (5, 7)*	4.5 (3, 5.25)	5.5 (3.75, 7)	5.5 (4, 7)	7 (5, 7)
How often were:						
Snack bars consumed/week	3.5 (3, 4)	6.25 (4.75, 10)*	3.5 (3.5, 5.5)	3.75 (3.5, 5.5)	3.5 (3.5, 5.5)	6.5 (4.75, 8.88)*
Fruit juice/week	1.5 (0.5, 3.13)	0.5 (0.5, 1.5)*	0.5 (0.5, 2)	0.5 (0.5, 1.5)	0.5 (0.5, 2)	0.5 (0.5, 0.75)
Soft drinks/week	0.5 (0, 0.5)	0 (0, 0.5)*	0.25 (0, 0.75)	0.5 (0, 1.5)	0.5 (0.5, 1.5)	0 (0, 0.5)
White bread†/week	0.5 (0.38, 3.5)	0.5 (0, 0.88)	0.5 (0, 2)	0.5 (0, 1.5)	0.5 (0, 1.5)	0.5 (0, 0.5)
Rice/week	1.5 (1.5, 1.5)	1.5 (0.5, 2)	1.5 (0.5, 2)	1.5 (0.5, 4)	1.5 (0.5, 4)	1.5 (1.5, 3.5)
Intake at specified amount/week						
Chocolates (25g)	0.75 (0.5, 3)	0.25 (0, 1.5)*	0.5 (0, 3)	1 (0.88, 3)	2 (0.5, 3)	1 (0.37, 3)
Lollies (small handful)	0.25 (0, 1.13)	0 (0, 0)	0 (0, 0.5)	0.5 (0, 1)	0.25 (0, 1)	0 (0, 0.62)
Biscuits‡, cake, pie (1 serving)	3.25 (1.38, 6.13)	1.25 (0.5, 3.75)*	3 (0.88, 4.12)	5 (3.13, 7.38)	5 (2, 6.25)	1.75 (1, 2)**

Median (interquartile range).

Within the same row same group, value was significantly different to baseline: *$p < 0.05$; ** $p < 0.01$ (Wilcoxon signed ranks test).

†White bread refers to breads made from wheat flour from which the bran and the germ layers have been removed.

‡Serving size was 2 pieces.

Table 14. Changes (Δ) in mean values (mmol mol^{-1}) of HbA1c at week 6 and week 12 in 28 subjects

	n	Baseline	HbA1c	ΔHbA1c	HbA1c	ΔHbA1c	HbA1c	ΔHbA1c
		(-1, 0 wk)	6 wk	6 wk	12 wk	12 wk	intervention	intervention
Group 1	14	36.1 (2.01)	35.5 (2.59)	-0.60 (1.30)	35.6 (2.17)	-0.53 (1.54)	-	-
Group 2	14	36.1 (2.14)	36.0 (2.71)	-0.14 (1.36)	35.9 (2.73)	-0.21 (1.32)	-	-
Pooled‡	28	36.1 (2.04)					35.7 (2.61)	-0.36 (1.32)*

Mean (standard deviation).

‡HbA1c pooled, HbA1c mean values in 28 subjects before and after the intervention: *$p = 0.165$ (repeated measures ANOVA).

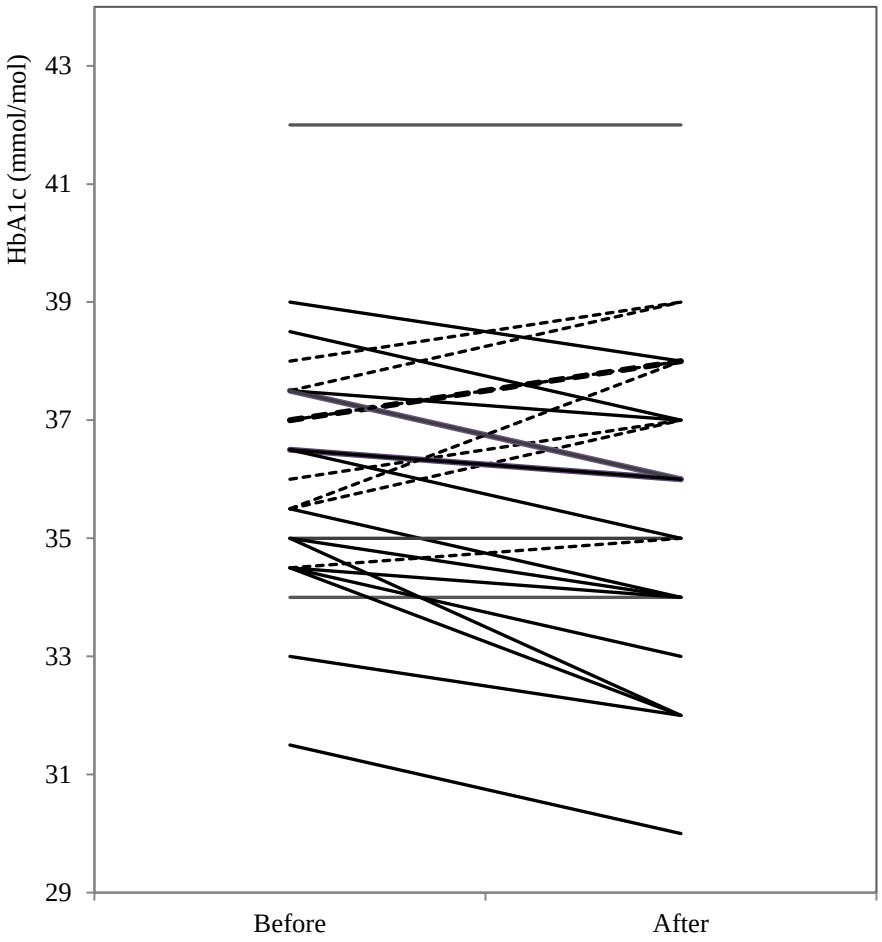


Figure 10. Changes in HbA1c of individual participant after a 6-week intervention (*n* = 28), before vs after intervention; dash, increase; solid line, decrease or no change.

Discussion

To our knowledge, this is the first study that has evaluated the effects of daily consumption of a healthier snack on snacking habits and glycaemic control over a 6-week period. There are two main findings. The first is that the participants found the bar acceptable and both anecdotally and from the self-reported snack diaries the 28 participants consumed at least 5 and up to 14 bars each week. The only exception was two participants who did not consume any bars for one week due to sickness. The second main finding is that after 6 weeks consumption of the Nothing Else bar as main snacks, there was overall a trivial decrease in HbA1c concentration. For three quarters of

the twenty-eight participants there was no change (n = 5) or a decrease (n = 15) in HbA1c from baseline. In other words, compliance with the intervention was good and there was a trend toward a favourable effect on glucose homeostasis.

Compliance with treatments and medication is a challenge to effecting behaviour change. A few intervention studies have investigated the effect of snacking on energy consumption and have shown that there was some energy compensation in normal weight participants (Bellisle, 2014). In contrast other studies showed that consumption of snack foods with high fat, sugar and salt reduces diet quality and promotes adiposity (Barnes, French, Harnack, Mitchell, & Wolfson, 2015; O'Connor, Brage, Griffin, Wareham, & Forouhi, 2015). This study did not seek to change snacking frequency but to replace less healthy usual snacks with a healthier option. It was assumed that some participants may not like the snack and withdraw from the study but this did not happen. After 6 weeks we have shown that repeated exposure increased the acceptance of a new type of snack, as has been demonstrated by others (Hausner, Hartvig, Reinbach, Wendin, & Bredie, 2012; Stein et al., 2003).

The increased number of the Nothing Else bars consumed during the intervention period was associated with a decrease in the number of other snacks so did not necessarily indicate an increase in energy consumption or snacking. Rather than change the frequency or time of snacking, we sought to change the availability of a healthier snack within the every-day environment and dietary pattern. Availability of healthier food products combined with health-related information has been associated with an improvement in dietary habits (Roy, Kelly, Rangan, & Allman-Farinelli, 2015). In the present study, participants were given the front, back of pack labels and explained the rationale of the “healthier” snack bar. The primary researcher visited participants weekly and the healthier snack was provided free of charge. While this would not happen in the real world, it is known that improved food literacy and environmental dietary

modification could improve the effectiveness of dietary interventions or changes in the food supply (Geaney et al., 2013). That is shown in the present study by the decrease in the consumption of less healthy usual snacks such as chocolates, biscuits, cakes, and pies during the time the healthier snack alternative was available.

Consumption of low GI foods, low GL diets (Jimenez-Cruz et al., 2003; Rizkalla et al., 2004) and dietary fibre (Jiang et al., 2012) are known to improve glycaemic control. Jimenez-Cruz et al. (2003) reported a significant reduction in HbA1c (from 8.5 ± 0.28% to 8.1 ± 0.24%, $p < 0.01$) after 6-week low GI diet treatment with 14 subjects. Rizkalla et al. (2004) also reported an improvement in HbA1c (from 7.56 ± 0.36% to 7.17 ± 0.39%, $p < 0.05$) after 4-week low GI diet treatment with 12 men with type 2 diabetes. Both studies were comparing the glucose profiles between low- and high-GI diets. In the present study, participants did not have hyperglycaemia and were asked only to replace their snacks; main meals were not controlled and dietary GL was not known. Whereas many studies reported that GI of food might play a more important role in glycaemic control (Brand-Miller et al., 2003; Jiang et al., 2012), some studies have shown that the effective glycaemic control (HbA1c) was attained when a low GI diet was associated with a low GL (Jimenez-Cruz et al., 2003; Rizkalla et al., 2004). Furthermore, even though the trial was arranged to avoid public holidays, some special occasions such as family events and a decrease in physical activity could confound the results. We propose that the factors discussed above may partially explain why eight participants had an increase in HbA1c after consumption of the snack bars for 6 weeks, given there was no difference in their baseline snacking habits and baseline HbA1c (Figure 10) compared to other participants.

The compliance and reported changes to snacking might be due to the Hawthorne effect (Schwartz, Fischhoff, Krishnamurti, & Sowell, 2013) related to the participants' awareness of participation in an experimental trial and observation because participants

were not blinded to the treatment. That was minimised by asking half the participants to delay the intervention for 6 weeks (a stepped wedge trial) but to complete the snacking habits questionnaire and their HbA1c to be measured for the first 6 weeks. This would allow the effect of participation to be accessed.

The main limitation of the present study is a common issue for intervention studies in that there was no control and the participants are free-living persons. Snacking habits were self-reported and there may be recall bias in the reported consumption of snacks. Information on the regularity of meal intakes was not recorded although high glycaemic impact/load foods such as white bread and rice were included in the questionnaire. Further, six weeks may not be long enough to see meaningful effects in HbA1c. Nevertheless, the design of the study represented real life, had a minimal participant burden, and there was high participation and compliance over the 12 weeks. This study is the proof-of-principle that changes in food supply and food branding and labelling have the potential to change dietary patterns and improve public health. Whether a similar effect of a healthier snack would be seen in a much longer term requires further study.

The Nothing Else bar was found acceptable as part of a daily dietary pattern. The bar, with its higher protein and fibre content and low GI, improved the nutritional quality of dietary snacking habits and likely to improve glycaemic control. It is concluded that changes in the food supply, together with ingredients and nutritional information, have the potential to improve habitual snacking behaviour and reduce the impact of poor nutrition on public health in the longer term.

Chapter 7

Overall Discussion and Conclusions

This PhD thesis has demonstrated that it is feasible for academia to work in partnership with the food industry to develop a unique branded food product, and to position and sell the product in a competitive environment. New knowledge from this work includes evidence that a novel way of providing consumers with front-of-pack information has favourable impact on consumer perception. What the Nothing Else brand adds to the current New Zealand front-of-pack health star rating scheme ("Health star ratings," 2016) is that all the ingredients are listed on the front of the pack. This is not a feature of any other food brand or product that could be found in the literature. While the nutrient profiling scheme is used to determine whether a health claim may be made, there is a nutrient-centric and arguably negative focus on energy, saturated fat, salt and positive on protein, fruits and dietary fibre. These components can be manipulated to achieve a better nutrient profiling score (FSANZ, 2015) but do not inform the consumer about additives and preservatives and the complexity of the ingredient list. In addition, the experimental trials provide evidence that the developed snack bar is a healthier option in terms of the improvement in glycaemia, satiety and habitual snack behavior in the short and longer term.

In this chapter, the primary findings from the four studies are summarised and compared with other studies on snack reformulation in relation to glycaemia, satiety, and habitual snacking behaviour. The concurrent on-site sales trial is briefly described as it supports the work of this thesis. The strengths and limitations of the current body of work are discussed, and the areas of future research are identified.

The primary findings

The four main outcomes of this original body of work were:

- A healthier snack bar, branded Nothing Else comprising eight natural ingredients, met the criteria of a nutrient profile required for high-level health claims (FSANZ, 2015), was developed and able to be manufactured commercially (Chapter 3)
- The bar was less liked compared to other popular snack bars, however, branding and labelling improved overall liking of the bar, from a branding and marketing perspective (Chapter 4)
- Glycaemic and satiety responses over two hours to the Nothing Else bar were favourable than for two commercial snack bars in the short term (Chapter 5)
- Favourable responses to daily consumption of the bar over 6 weeks were observed in terms of habitual snacking behaviour and glycated haemoglobin concentration in a 6-week intervention (Chapter 6)

In addition, right from initiation, this multidisciplinary project had pathways to commercialisation as part of the design and manufacturing process, this included continual involvement of a commercial food manufacturer. The university provided the environment for sales trials through cafes and Sport and Fitness centres, the expertise of creative communication staff in the Nothing Else branding and principles informed the criteria, and long term there was ability for the snack bars developed along the same principles to be baked and packaged in commercial quantities. All this was realised within a four-year PhD journey.

This work was based on the premise that food reformulation could improve nutritional quality of foods and improve public health. This is a stated focus of both governments and food industry (Combris et al., 2011; Friel et al., 2015; Hawkes et al.,

2015). Initiatives to reformulate foods include reformulations to reduce salt (Webster et al., 2010), to reduce sugar (Hashem, He, & MacGregor, 2016), and as a consequence to reduce glycaemic index/load and improve satiety (Burton et al., 2011). The study of the Nothing Else bar adds to the evidence that the public will consume low GI and satiety-enhancing food products. Few products of this type have successfully endured in the market (Mercer, 2013), due to lack of taste appeal, sustainable ingredients and proven product effectiveness. The Nothing Else bar was particularly challenged by taste appeal because its sugar and fat content was lower than that of other bars. In a wider context, food reformulation is influenced by other policies such as labelling, nutrient profiling, product composition, and health claims (Webster & Hawkes, 2009). Further, successful food reformulation is measured by consumer behaviour, the scientific proof of effects on dietary intake and public health (Webster & Hawkes, 2009). All these aspects have been considered in this work.

Technical approaches to develop a healthier snack

Food reformulation for health involves rebalancing macronutrients and using unrefined ingredients to improve the nutrient profile of food products. The development of the Nothing Else bar involved technical and nutrition expertise cross-discipline. The candidate ingredients were selected for a combination of the three macronutrient categories: protein, fat, carbohydrate. Potential technical approaches included reducing the contents of fat and sugar, increasing the content of protein, increasing slowly digested carbohydrate, and adding dietary fibre to reduce energy density.

The Nothing Else healthier snack bar was developed using the nutrient profiling scheme as a guideline (FSANZ, 2015). Ingredients selection was based on nutrition quality, mixing and moulding properties to ensure consistent dimensions, and a low water activity to ensure shelf stability. The health benefits of selected ingredients contributed to the overall health and nutrition profiles of the bar, as have been

demonstrated by studies on oats (Slavin, 2004), oat bran (Tapola et al., 2005), almonds (Kendall et al., 2010), and cinnamon (Akilen et al., 2012; Blevins et al., 2007). Honey was used as the humectant to retain shelf stability of the snack bar without preservatives, and to help the bar maintain cohesion.

The shelf stability of the Nothing Else bar without preservatives has been a challenge. During the industrial production, the water activity (a_w) was monitored and the bars were baked to achieve a water activity lower than 0.7.

Consumers liking of reformulated food products

Reformulation can alter food structure and influence consumers' acceptance, and taste appeal is always a challenge for food reformulation. Consumers might not accept or less like the reformulated food products with reduced fat and sugar. In an informal consumer study trial for the Nothing Else bar, the questions of "will people eat the bar and will they buy it" were addressed. Two thirds of the 50 consumers said that they would eat and buy the bar. In addition, the consumer liking study showed that compared to four commercial snack products selected from top New Zealand brands, the Nothing Else bar was least overall liked (Yan et al., 2015). The Nothing Else bar had less fat and the least sugar content of all the snack products tested. Fat and sugar in foods are perceived as mouthfeel enhancers and flavour carriers that greatly affect consumers' acceptance of a food product (Drewnowski, 1989; Guinard et al., 1997; Guinard et al., 1996).

Although taste is the most important impact factor for sensory acceptability, consumer liking of a healthier food can be influenced by attitudes, health interest and consciousness (Fernqvist & Ekelund, 2014). In the present study, the overall liking of the Nothing Else bar was improved by 14% with packaging and brand knowledge (Yan et al., 2015), while the overall likings of other commercial bars did not change. These

findings suggested that branding and health related nutrition information were associated with improved consumer liking and brand perception. Moreover, the results confirmed that raising consumers' awareness of naturalness, healthiness could be improved by labelling, in particular front-of-pack labelling.

In the intervention study of this thesis, participants were provided free snack bars for 6 weeks and about 90% of the bars were self-reported to have been eaten as directed. This is in agreement with and adds to others work that repeated exposure to a new product type could increase liking (Hausner et al., 2012; Stein et al., 2003).

Scientific proof of health impact

The Nothing Else snack bar had favourable effects on blood glucose and satiety. The nutrient profile and physical structure of the snack bar, which is dependent on the quantity and properties of the ingredients, are most likely the origin for this. While macronutrient composition and physical properties of foods exert different physiological effects on blood glucose concentration and sensation of satiety (Norden, 2009), it is hard to implicate the action of one component.

The recipe for the Nothing Else bar was formulated to contain a balance of macronutrients and structure-related factors that have beneficial effects on glycaemic and satiety. There is evidence that among the three macronutrients, protein has a more favourable effect on glycaemic response and satiety (Anderson & Moore, 2004; Astrup, 2006; Westerterp-Plantenga, 2003). The Nothing Else bar had higher protein (12.5% of energy) than the commercial bars. In addition, the dietary fibre (8.2 g/100 g) also would be associated with a reduced glycaemic impact and regulation of hunger, due to its non-digestible property (Clark & Slavin, 2013). However, in spite of a large number of studies over many years, the results on GI, GL in relation to health have been inconsistent (Sluijs et al., 2013; van Aerde et al., 2012). The influence of nutrients of

food on appetite regulation and weight management is not clearly understood (Crino et al., 2015).

However, in agreement with others work, this study supports the contention that low GI foods and low GL diets have positive effects on medium term glycaemic control (Brand-Miller et al., 2003; Jimenez-Cruz et al., 2003; Rizkalla et al., 2004). In particular, ingredients used in the Nothing Else bar include oat bran that improves glycaemic, insulinmic and lipidemic responses (Pick et al., 1996; Tapola et al., 2005). Dietary fibre promotes regulation of appetite and reduces the risk of developing obesity (Kristensen & Jensen, 2011; Yuan et al., 2014), and lowers HbA1c (Jiang et al., 2012). In addition, relatively high protein content from the nuts such as almonds improved sensation of fullness (Gonzalez-Anton et al., 2015; Rebello, Greenway, & Dhurandhar, 2014). However, longer term trials are required to determine the effect on weight loss and decrease of metabolic risk factors.

There have been a number of studies on snack or snack reformulation in relation to health impact (Table 15). The replacement of refined carbohydrate and fat with fibre and protein in snack bars promoted satiety and improved glucose and insulin profiles (Williams et al., 2006). Snacking on almonds, in comparison to cereal bars, induced a higher eating frequency (Zaveri & Drummond, 2009). Vitaglione et al. (2010) reported that replacing 70% of wheat flour with β-glucan enriched barley flour in krumiri-type biscuits increased feeling of fullness. Leidy et al. (2015) examined the satiety effects of soy puddings with high protein or high fat content, and found that high protein (38% of energy as protein) soy pudding delayed eating initiation and reduced appetite. Oat bran or psyllium fibre addition reduced the glycaemic effects of extruded snacks (Brennan, Derbyshire, Brennan, & Tiwari, 2012). However, these studies largely focused on nutrients rather than a whole food product. Although a few studies have investigated product composition, for example Williams et al. (2006), the nutrient profiles of the test

snacks were undeclared. In contrast, the present study investigated a real product that met nutrient profiling scoring criterion for health claims, and had favourable short term effects on glycaemic and satiety responses (Yan et al., 2017).

The health impact of snack reformulation has also been demonstrated in medium term intervention studies (Table 15). Pelkman, Navia, Miller, and Pohle (2007) reported that consumption of a calcium-gelled fibre beverage twice a day reduced energy intake in overweight and obese women. In a 12-week parallel study, snacking on cereal bars, in comparison to almonds, promoted a lower eating frequency; neither snack resulted in weight gain (Zaveri & Drummond, 2009). In another 12-week parallel study, Tey, Brown, Gray, Chisholm, and Delahunty (2012) demonstrated that consumption of energy dense snack foods (hazelnuts, chocolate, and potato chips) increased food and energy intake. Johnston, Trier, and Fleming (2013) investigated the effects of intake of peanut and grain bar as preloads before a standardised meal on post-meal satiety, glycaemia, and weight loss in healthy individuals, and found that both preloads were associated with a small but statistically significant improvement in HbA1c (0.2%, p = 0.001). In addition, the grain bar preload was associated with improved satiety and significant weight loss (~1.3 ± 0.4 kg) over 8 weeks. The present study investigated the effects of daily consumption of the Nothing Else bar for 6 weeks on snacking habits and HbA1c. The availability of a healthier snack within the every-day environment, together with ingredients and nutritional information, have the potential to improve habitual snacking behaviour and reduce the impact of poor nutrition on public health in the longer term.

Sales

Concurrent sales of the Nothing Else snack bar through 2014-2015 within a retail university environment had been steady (Rush et al., 2016): more than 10,000 bars were sold within one year and repeat and multiple purchases were observed.

Currently, more than 1000 of the Nothing Else bars are sold per month across three cafes at AUT campuses (personal communication with YoYo Fu, Cafe co-ordinator, AUT hospitality services). This is evidence that the product is acceptable to consumers in a commercial environment.

It is always challenging to launch a food product with a new concept. However, the sales trial of the Nothing Else snack bar revealed that repeated consumption, branding and health-related information may increase the acceptance of and preference for healthier snack foods of this type.

Strengths and limitations

This study has been a unique collaboration between researchers, an academic institution, the food industry and consumers themselves. This cross-discipline collaboration combined with creative communication expertise resulted in an innovative product and a focused testing regime.

This work is translational science where a university, in partnership with industry, was able to develop a healthier snack bar with validated health claims that was ready to be scaled up to commercial production and a sales trial (Rush et al., 2016). To our knowledge, this is the first time that an investigation has examined the relationships between the nutrition profile, glycaemic response, and satiety and hunger for a specific product and produced peer reviewed articles that documented the process. The bar was tested at serving size rather than for 25 or 50 g of available carbohydrate as is required for the determination of glycaemic index. In addition, provision of an opportunity for consumers to choose a food product with a clinically validated health benefit was made available. Further, this study is the first to report the short and long term effects of a low GI healthier snack on glycaemia, satiety and snacking habits and glycaemic control over

six weeks. Thus, evidence that one way of improving the nutritional quality of the food supply without compromising commercial viability has been documented.

There were a number of limitations in the current body of work. In the three investigations, the relatively small numbers of participants were university staff and students who do not represent the wide population. The effect sizes were relatively small, and more participants and a longer time for the intervention would have increased the power. In the study of snack bar composition and glycaemic response, insulin resistance was not measured and in a different population, e.g. with impaired glucose tolerance, the response may be different and different biomarkers of effect could be used. The time of measurement of the effects on satiety and glycaemia was limited to two hours following consumption of a bar with water only. In practice, consumption of a snack bar would be with other drinks such as milky tea or coffee. In the 6-week intervention study, there was no control or standardisation of diet; the participants were free-living persons. Supply of bars free of charge and delivered weekly did not emulate the situation of everyday life. However, all participants reported that they regularly snacked. Further, 6 weeks may not be long enough to see meaningful effects on HbA1c or to determine whether the changes in snacking behaviour would persist after the completion of the study. In future studies changes in weight, bowel habits, cholesterol and fasting insulin could also be measured as could the effect of asking participants to buy the snack bar rather than have it provided. Other areas that were not investigated include the pricing of the snack bar, distribution channels, the availability of the bar at other commercial outlets and effects of marketing and branding in the wider world.

Areas of future research

The improvement of the food environment for better health is one important area for research recognised by international bodies and governments. This work has identified one small way that the food supply may be changed and which does not involve individual intervention but does involve the food industry and organisations such as universities.

In 2011, the global priority for prevention of chronic diseases was recognised by a summit meeting of the United Nations, and objectives were set up for the development of global policy and action plans (World Health Organisation, 2013). The summary documents state that despite the effort made in the past decades to prevent and delay the onset chronic diseases, the prevalence of the epidemic is growing around the world, which comes to be one of the major social challenges. Diet and nutrition are the major modifiable risk factors in relation to chronic diseases. Reduction of the burden through changes in dietary patterns would possibly benefit public health, and such changes would necessitate changes in improving the food supply (Butland et al., 2007; Kennedy et al., 2011) but also creating economic opportunities within a sustainable economic framework. There has presently been a growing body of health research into the effects of changes on diet and nutrition related to health outcomes. However, there has been very little research focus on the translation of research into practical changes in the food environment. Financial gain remains a priority of much of the food industry.

The evidence presented in this thesis of how working with a food industry partner and a healthier food product can be produced, sold and consumed, needs to be expanded and extended to other products. While the goal of the New Zealand high value nutrition science challenge to produce high-value food products with validated health claims has been demonstrated, the challenge is not intended to meet the needs of those living in disadvantaged circumstances. The goal is to make money by exporting products with

added value and verified health claims to markets where presumably the products will be bought by those with disposable income.

Food reformulation is promoted by governments, and reformulation should be evidence-based and led by, or with, the food industry. Nevertheless, will food reformulation in isolation provide an efficient solution to the challenge of improving dietary patterns (Buttriss, 2013)? Furthermore, will food reformulation result in beneficial health outcomes equitably? These questions need to be answered. In addition, it needs to be recognised that food reformulation introduces costs to food businesses that employ a large number of people and have financial obligations. Reformulated products should not impact on the commercial viability of the company. This work was possible because of the generosity and time of AB Foods Ltd., a family owned company, but if the work were to be translated into other settings, more attention would need to be paid to the business model from production to the point of final sale.

Public health promotion and health research is a worldwide endeavour sustained by governments, industry, and organisations around the world. However very little of research money or even health promotion money is for prevention of disease. Most is around treatment (Organisation for Economic Cooperation and Development, 2015). This underlines the need for collaboration from all sectors, and focusing industrial practices on all socio economic groups. There is a lot more work required in this area including analysis of sales data to measure changes in the food supply (Swinburn, Dominick, & Vandevijvere, 2014).

In New Zealand, high value nutrition is one of the national science challenges and a priority for the Ministry of Business, Innovation and Employment (2013). There is a need to link food production and sales with leverage of foods that have a nutrition profile and evidence that supports high level health claims. Future innovative work in improvement of the food supply could be done through innovation to develop a wide

range of novel food types; validate the prototypes in human trials by demonstrating the effects on biomarkers, nutrient bioavailability and behaviour; consequently investigate long term consumer and health benefits; moreover, and evaluate sensory consumer liking from a marketing point of view. Although these are all worthy aims and principles, implementing these within New Zealand for the local population can be very challenging. However, if successful, these benefits would have application to other countries.

Future work should also include investigations of how to improve consumer understanding of nutrition and training in ways of shopping and selecting foods to achieve a healthier diet overall. The development of healthier food products will need to be considered equally with the consumer needs versus wants, so such an approach could be translated into relevant dietary changes associated with healthier eating habits.

Furthermore, the New Zealand economy is based on agricultural production. In recent decades, New Zealand has developed international reputation in food safety and quality related to the natural environment. Further snack bar development using local ingredients such as oats, oat bran, flaxseed, honey would add values with natural resources to supply for domestic consumers but also export markets.

Table 15. Comparison of the present study and other studies on snack reformulation in relation to glycaemia, satiety and snacking behaviour

Author(s)	Snack type	Key finding(s)			
		Acute glycaemic and satiety	Intervention		Consumer liking
			Design	Behaviour and glycaemia	
Yan, this thesis	Snack bar: eight perceived natural ingredients; formulation chosen to meet NPSC for health claims	30% lower in iAUC over 2 hours compared to the test commercial bar of equal weight; promotes reduced hunger (*n* = 26)	Stepped wedge (13 weeks)	Significant reduction in intake of biscuits, cakes, and pies; 20 participants (71.4%) out of 28 experienced a decrease or no change in HbA1c (*n* = 28)	Liked when branding and nutrition information provided (*n* = 64)
Leidy et al. (2015)	Soy pudding: high-protein (HP, 38% of energy as protein), or high-fat (HF, 43% of energy as fat) vs. no snack (NoS)	HP, but not HF, delayed eating initiation vs. NoS; both HP and HF snacks reduced appetite vs. NoS (*n* = 31)			
El Khoury et al. (2014)	Yogurt: plain, plain with honey or strawberry or skim milk or orange juice	Increasing protein to carbohydrate ratio in yogurt reduced glucose iAUC; no observable changes in satiety (*n* = 20)			
Douglas, Ortinau, Hoertel, and Leidy (2013)	Yogurt: low, moderate or high protein content vs. NoS	HP yogurt reduced hunger, increased fullness, and delayed subsequent eating (*n* = 15)			
Johnston et al. (2013)	A preload of peanut vs. grain bar	Grain bar preload elevated satiety (*n* = 15)	Parallel (8 weeks)	Compared to consumption of peanut preload (*n* = 23), grain bar (*n* = 21) prompted weight loss; HbA1c decreased in both treatments	

Author(s)	Snack type	Key finding(s)		
		Acute glycaemic and satiety	Intervention	
			Design	Behaviour and glycamia
Brennan et al. (2012)	Extruded snack: oat bran or psyllium fibre addition	Both oat bran and psyllium addition reduced glycaemic responses (*n* = 12)		
Tey et al. (2012)	Hazelnuts, dairy milk chocolate, and potato chips vs. control		Parallel (12 weeks)	Food intake increased with all three snack groups, hazelnuts (*n* = 32), chocolate (*n* = 33), potato chips (*n* = 28), but not in control group (*n* = 29)
Farajian, Katsagani, and Zampelas (2010)	A preload of dried prunes vs. white bread	Dried prunes improved satiating effect, reduced energy intake (*n* = 45)		
Vitaglione et al. (2010)	A preload of barley β-glucan enriched vs. biscuits	β-glucan enriched preload reduced the desire to eat, increased fullness and satiety (*n* = 20)		
Zaveri and Drummond (2009)	Cereal bar, almonds vs. control		Parallel (12 weeks)	Almonds promoted a higher eating frequency; both cereal bar (*n* = 13) and almonds (*n* = 11) did not result weight gain
Pelkman et al. (2007)	Beverage: alginate pectin addition		Crossover (1 week)	Pectin (gel forming fibre) addition reduced energy intake (*n* = 29)

Author(s)	Snack type	Key finding(s)
		Acute glycaemic and satiety
Williams et al. (2006)	Snack bar: high protein (HP) high fibre vs. high fat (HF) high sugar	HP induced 16% lower glycaemic response; improved insulin profile; induced 5% reduction in energy intake (*n* = 18)

NPSC: nutrient profiling scoring criterion (FSANZ, 2015), a food with a NPS > 4 is unable to make health claims.

HP: high protein; HF: high fat; NoS: no snack

iAUC: incremental area under the curve

Conclusions

This collective body of work presents a proof of concept and evidence for the feasibility of development of a healthier commercial food product by a university in partnership with the food industry. The integration and translation of diverse skills, such as health and nutrition; food science; marketing; creative communication into a final product is one small step towards providing a food environment that is supportive of healthier dietary patterns.

What this thesis adds to the literature is new insights into how research informs practice. The dissemination of the results and discussion of the findings were ongoing so that the commercial partner was part of the process. Therefore, this was a multi-layered, cross-disciplinary participatory research project that has added to the understanding of consumer behaviour towards healthier foods, and documented some health benefits of this approach and the product.

The next challenge is for others to adopt this participatory approach to changing the nutritional quality of the food supply without compromising any participant.

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Appendices

Appendix A. Questionnaires

Consumer Testing

Which snack bar and why?

Please state your age _____yrs

Ethnicity _____

Dietary pattern (if there is anything you do not eat)?

_____

How often do you consume snack bars?

- ☐ Occasionally
- ☐ Once per month
- ☐ Once per week
- ☐ Several times per week
- ☐ Once per day
- ☐ Several times per day

Are you (please tick)

- ☐ Male
- ☐ Female

Do you have any allergies associated with

nuts	□Yes	□ No
gluten	□Yes	□ No
egg	□Yes	□ No
milk	□Yes	□ No
colours	□Yes	□ No

Anything else please name

_____

* If you have any allergies associated with food ingredients that may be in a snack bar please do not proceed with this test

Instructions: The testing will be in two steps. Please follow the instruction of each step.

Step One:
There are 6 questionnaires provided - one for each snack bar which is identified by a number on the plate and on the questionnaire.
Consider each snack bar one at a time.

Before you taste each snack bar please rinse your mouth out with water before tasting.

Xxx

Xxx

Xxx

Xxx

Xxx

Xxx

Snack bar number Xxx

Rinse your mouth out with water first.

For your liking of this snack bar please put a | mark on the line scale below to show how much you like each characteristics.

Please taste the snack bar and score how much do you like or dislike the product overall

Extremely Dislike — Extremely Like

Overall liking

Extremely Dislike — Extremely Like

Appearance

Extremely Dislike — Extremely Like

Taste

Extremely Dislike — Extremely Like

Flavour

Extremely Dislike — Extremely Like

Texture

Please rinse your mouth and go on taste the next snack bar.

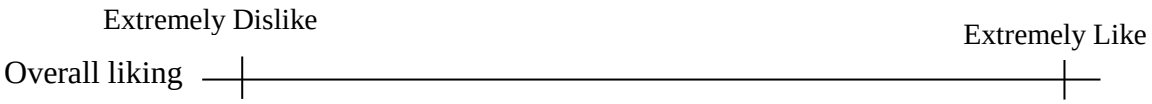
Step Two:
There are 5 questionnaires provided - one for each snack bar which is presented to you together with its front and back packs showing the brand, the ingredients and nutrition information, you read the information then taste the snack bar.
Consider each snack bar one at a time.
Before you taste each snack bar please rinse your mouth out with water before tasting.

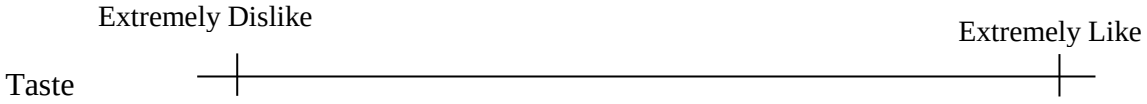
Snack bar name

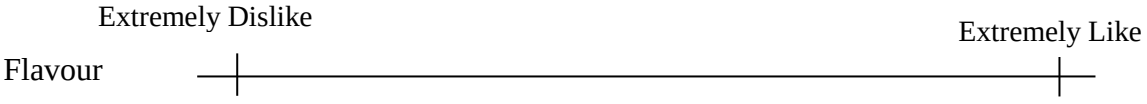
Rinse your mouth out with water first.

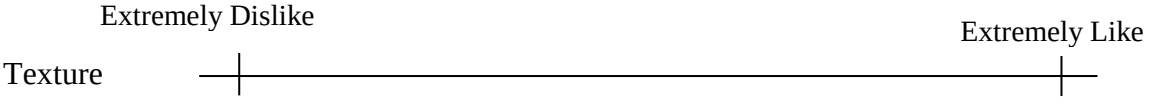
For your liking of this snack bar please put a | mark on the line scale below to show how much you like each characteristics

Please taste the snack bar and score how much do you like or dislike the product overall









Please rinse your mouth and go on taste the next snack bar.

Please rank the five bars from 1 to 5 for each characteristics, then state how important of healthiness, taste, naturalness to you (1 = not important, 5 = very important)

	Healthiness 1 = least healthy, 5 = healthiest	Taste 1 = least preferred, 5 = most preferred	Naturalness 1 = least natural, 5 = most natural	Purchase Intent if all cost the same 1 = least likely, 5 = most likely
Nothing Else				
Tasti				
Nice & Natural				
Mother Earth				
Sanitarium				
How important				

Thank you for participating in this project

Satiety effect of snack bars

Please state your age _____yrs Ethnicity _____

Are you (please tick)

- ☐ Male
- ☐ Female

Name of the snack bar _____

This questionnaire is to be completed 1 time before eating and 6 times after eating, that is, immediately after consumption and then after each finger-prick.

Please place a ‘ | ’ on the line of each question to indicate the extent of your feeling

Satiety test before eating

How strong is your desire to eat?

Very weak ——— Very strong

How hungry do you feel?

Not at all ——— Extremely hungry

How full do you feel?

Not at all ——— Extremely full

How much food do you think you could eat?

Nothing at all ——— A large amount

Satiety tests after eating

Satiety test 1 -15 minutes after eating

How strong is your desire to eat?

Very weak — Very strong

How hungry do you feel?

Not at all — Extremely hungry

How full do you feel?

Not at all — Extremely full

How much food do you think you could eat?

Nothing at all — A large amount

Satiety test 2 -30 minutes after eating

How strong is your desire to eat?

Very weak — Very strong

How hungry do you feel?

Not at all — Extremely hungry

How full do you feel?

Not at all — Extremely full

How much food do you think you could eat?

Nothing at all — A large amount

Satiety test 3 -45 minutes after eating

How strong is your desire to eat?

Very weak — Very strong

How hungry do you feel?

Not at all — Extremely hungry

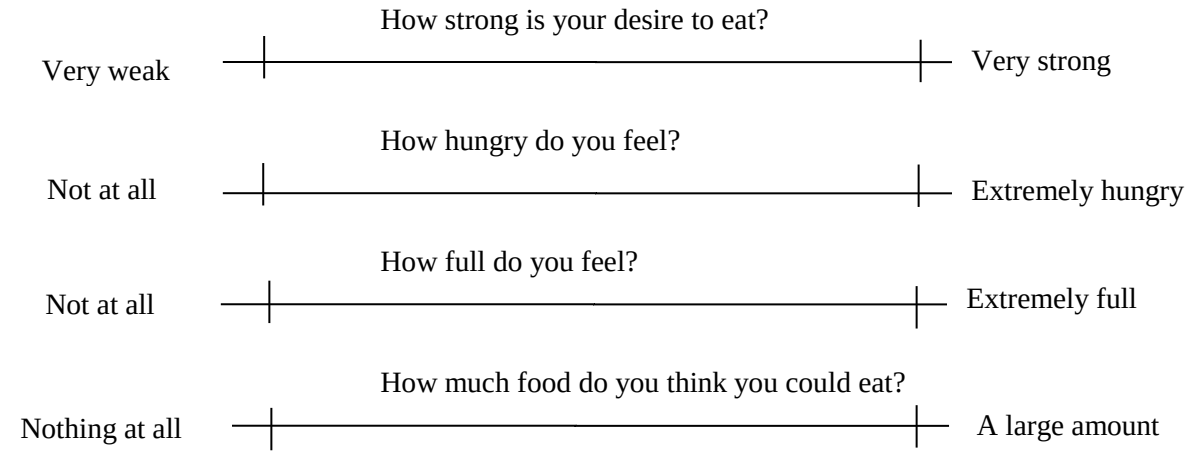
How full do you feel?

Not at all — Extremely full

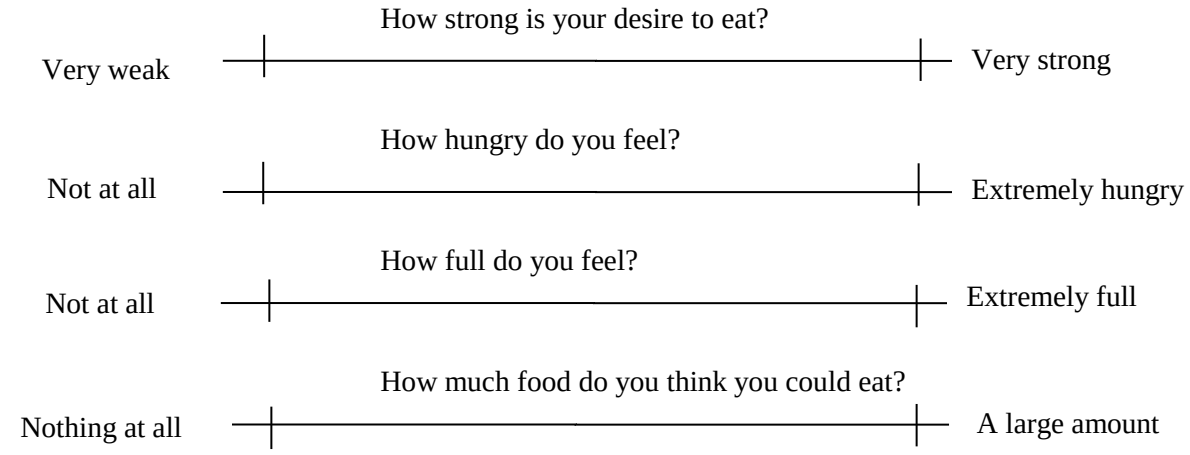
How much food do you think you could eat?

Nothing at all — A large amount

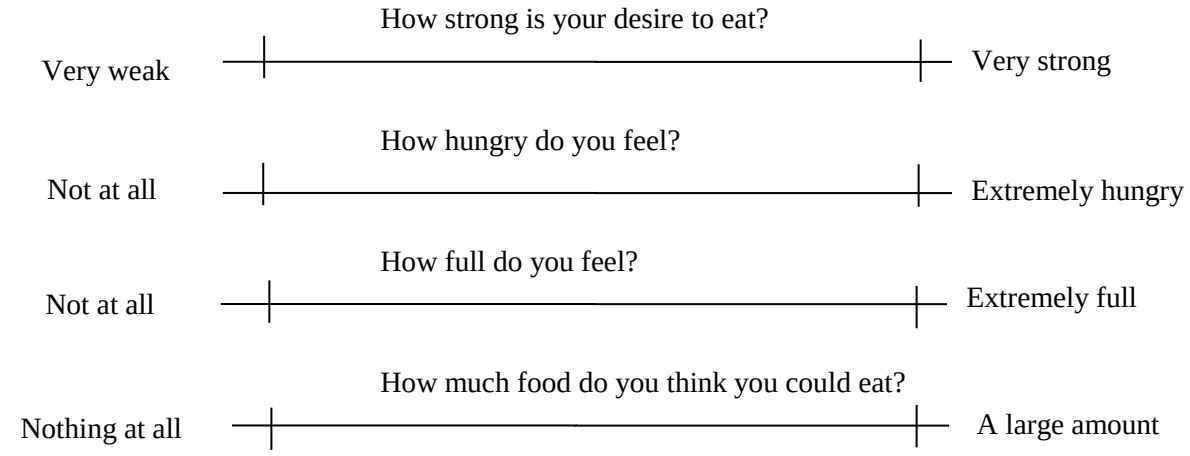
Satiety test 4 -60 minutes after eating



Satiety test 5 -90 minutes after eating



Satiety test 6 -120 minutes after eating



Thank you for participating in this project

Dietary snack habits questionnaire

Please state your age _____yrs

Are you (please tick)

- ☐ Male
- ☐ Female

Physical activity level at work (choose 1 to 4) _____

Physical activity level at leisure time (choose 1 to 5) _____
(The researcher will show a card that explains the way to estimate your physical activity level)

Session One

Introduction: I am going to ask you some questions about your usual eating patterns, **the frequency** of intake of specific foods. When answering these questions please think back over the past six weeks. Remember to think about all times when you eat both at home and away from home.

No.	Question	Response	Comments
1	How many days in an average week do you have something to eat as snack? You may have eaten at home, in a car, at work or in a café. Interviewer note: a) includes both weekends and weekdays b) examples are lollies, chocolate, snack bars and baked goods such as cakes, muffins, cookies c) snack is a small portion of food eaten between main meals	Participant to choose number of days 1 to 7 _____ Don't know Refused	
2	How many snack bars (at the serving size) in an average week do you eat? Interviewer note: Participants need to be regular snack bar consumers who eat 3-4 snack bars per week at least	3-4 per week 5-6 per week 7 or more per week Indicate the number if more than 7 bars per week _____	

3	How often do you drink fruit juices and drinks? Do not include diet or diabetic varieties. Fruit juices and drinks include freshly squeezed varieties, and brands such as Just Juice, Fresh-up, Keri, Golden Circle, Ribena and Charlie's. Excludes – 'diet varieties', soft drinks, energy drinks, flavoured waters, and sports waters	Never Less than once per week 1-2 times per week 3-4 times per week 5-6 times per week 7 or more times per week Don't know Refused	
4	How often do you drink soft drinks or energy drinks? Do not include diet varieties. Soft drinks are often carbonated/ 'fizzy' and includes coca-cola, pepsi, lemonade, ginger beer, energy drinks ('V', Red Bull, Lift plus), powerade, E2, G-force. Excludes – 'diet varieties', fruit juices and drinks, flavoured waters, and sports waters	Never Less than once per week 1-2 times per week 3-4 times per week 5-6 times per week 7 or more times per week Don't know Refused	
5	How often do you eat white bread? White bread refers to breads made from wheat flour from which the bran and the germ layers have been removed	Never Less than once per week 1-2 times per week 3-4 times per week 5-6 times per week 7 or more times per week Don't know Refused	
6	How often do you eat rice? Include white rice, brown rice, parboiled rice	Never Less than once per week 1-2 times per week 3-4 times per week 5-6 times per week 7 or more times per week Don't know Refused	

Session Two

Introduction: This session measures how often on average you have eaten **a specified amount** of food. When answering these questions please think back over the past six weeks. Remember to think about all times when you eat both at home and away from home. Pleas tick (√) the circle which best tells.

Food	Serving size	Never or less than once per month	1-3 per month	1 per week	2-4 per week	5-6 per week	1 per day	2-3 per day	4- 6 per day
Sweets, baked goods, miscellaneous									
Chocolate/chocolate bars	5 squares (25g)	◯	◯	◯	◯	◯	◯	◯	◯
Sweets, lollies	Small handful	◯	◯	◯	◯	◯	◯	◯	◯
Biscuits	2	◯	◯	◯	◯	◯	◯	◯	◯
Cake	1 serving	◯	◯	◯	◯	◯	◯	◯	◯
Brownie	1 serving	◯	◯	◯	◯	◯	◯	◯	◯
Pie	1 serving	◯	◯	◯	◯	◯	◯	◯	◯
Danish	1 serving	◯	◯	◯	◯	◯	◯	◯	◯
Sweet scone	1 serving	◯	◯	◯	◯	◯	◯	◯	◯
Pancake	1 serving	◯	◯	◯	◯	◯	◯	◯	◯
Muesli bars	1 serving	◯	◯	◯	◯	◯	◯	◯	◯
Any other _____	1 serving	◯	◯	◯	◯	◯	◯	◯	◯
White bread, rice									
White bread	2 slices/ 1 roll	◯	◯	◯	◯	◯	◯	◯	◯
White rice	1 cup	◯	◯	◯	◯	◯	◯	◯	◯
Brown rice	1 cup	◯	◯	◯	◯	◯	◯	◯	◯
Parboiled rice	1 cup	◯	◯	◯	◯	◯	◯	◯	◯

Thank you for participating in this project

Appendix B: Ethics Approvals

AUTEC SECRETARIAT

19 November 2013

Elaine Rush

Faculty of Health and Environmental Sciences

Dear Elaine

Re Ethics Application: 13/184 Nothing Else: A healthier snack bar. Which snack bar and why? Study 2

Thank you for providing evidence as requested, which satisfies the points raised by the AUT University Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 18 November 2016.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online throughhttp://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 18 November 2016;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 18 November 2016 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this. If your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply there.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor

Executive Secretary

Auckland University of Technology Ethics Committee

Cc: Mary Yan maryan@aut.ac.nz

AUTEC
SECRETARIAT

25 November 2014

Elaine Rush

Faculty of Health and Environmental Sciences

Dear Elaine

Re Ethics Application: 14/342 Glycaemic responses and satiety effects of snack bars. Study 3

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 24 November 2017.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 24 November 2017;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 24 November 2017 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this. If your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply there.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor

Executive Secretary

Auckland University of Technology Ethics Committee

Cc: Mary Yan maryan@aut.ac.nz

AUTEC
SECRETARIAT

17 December 2014

Elaine Rush

Faculty of Health and Environmental Sciences

Dear Elaine

Re Ethics Application: 14/379 Glycaemic impact of consumption of the Nothing Else snack bar. Stage 4

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 17 December 2017.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 17 December 2017;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 17 December 2017 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to

the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this. If your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply there.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor

Executive Secretary

Auckland University of Technology Ethics Committee

Cc: Mary Yan, maryan@aut.ac.nz

Appendix C: Participant Information Sheets

Participant Information Sheet

Project Title:

Which snack bar and why?

An Invitation

Hi, my name is Mary Yan, a PhD student in the School of Sport & Recreation at AUT University. I would like to invite you to participate in a sensory trial (it is part of my PhD thesis) to compare the sensory characteristics of snack bars and to say which one you would eat and why.

Your participation is highly valued and is entirely voluntary. You may withdraw at any time without any adverse consequences.

What is the purpose of this research?

Successful marketing food is a challenge. There is an increasing demand for healthy, high quality foods that are associated with disease prevention and promotion of health in recent years. This study is designed to understand better why customers prefer some snack bars compared with others.

How was I identified and why am I being invited to participate in this research?

If you are 18 years or older, consume muesli bars at least once a week, and have no known allergies to food ingredients including nuts, gluten, egg, and milk, you are the participant we are looking for.

What will happen in this research?

- You will visit the sensory laboratory at AUT city campus or the postgraduate research room at Akoranga once, at around 11.00 am in the morning, at least two

hours after breakfast. You will be required to have no food or drinks except water for one hour before the test.

- A questionnaire asking about your age, gender, food patterns (i.e. if there is anything you do not eat) and ethnicity will be filled out by you on the day of the visit.
- The testing will be in two steps. In step one, you will be presented with the samples of six snack bars and asked to describe your liking of the colour, flavor, texture, sweetness and overall liking. You will rinse your mouth with water between each sample.
- In step two, five snack bars will be presented to you together with the front and back packs showing all the ingredients and nutrition information. You read the information, consume each bar and describe your liking of the colour, flavor, texture, sweetness and overall liking.
- When this is completed you will be asked to state how important of healthiness, taste, naturalness to you and rank the five bars.
- You will be asked not to discuss your ratings with others.

What are the discomforts and risks? How will these discomforts and risks be alleviated?

There are no known discomforts or risks. This will take around one hour of your time.

What are the benefits?

The information that you provide will help understanding of taste and branding preferences of different groups of people.

How will my privacy be protected?

Your results will be kept confidential, with only the named researchers having access to the data. The research assistant will be requested to sign a confidentiality agreement. All uses of data in reports, journal articles, and conference papers will be summary data

so that you will not be identifiable in any way. The data may be used to inform further studies in this area. The raw data will be retained in secure storage for six years, after which it will be destroyed as required by the University's research policy. You will receive the summary of the research findings.

What opportunity do I have to consider this invitation? How do I agree to participate in this research?

After you have read this information sheet and if you would like to participate contact me to make an appointment to discuss the project in more details. If after that you agree to participate you will be asked to sign a consent form and to arrange a time for the first of your three testing visits. You may ask questions at any time and withdraw from the project without any disadvantage at any time. You have two weeks in which to consider whether or not you wish to take part in this research.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Professor Elaine Rush, elaine.rush@aut.ac.nz AUT University, Phone 021 624 077

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, ethics@aut.ac.nz , 09 921 9999 ext 6038.

Whom do I contact for further information about this research?

Researcher Contact Details:

Mary Yan, myan@unitec.ac.nz, Phone 021 044 1561

Project Supervisors Contact Details:

Professor Elaine Rush, AUT University, Phone 021 624 077

Approved by the Auckland University of Technology Ethics Committee, AUTEC Reference number *13/184.*

Participant Information Sheet

Project Title:

Glycaemic Responses and Satiety Effects of Snack Bars

An Invitation

Hi, my name is Mary Yan, a PhD student in the School of Sport & Recreation at AUT University. I would like to invite you to participate in a research project, which involves investigating the glycaemic and satiety effects of a newly developed snack bar in comparison with two commercial bars.

Twenty-six volunteers are required for the study, which will be conducted at AUT South campus and Unitec Mt Albert campus.

Please read this information sheet carefully before deciding whether or not to volunteer. If you decide you would like to participate please contact me. The contact details are shown below. If you decide not to take part there will be no disadvantage to you and I thank you for considering my request.

What is the purpose of this research?

The study is designed to investigate the glycaemic response (what happens to blood glucose concentration after eating) of a newly developed healthier snack bar, and also its satiety effect (how well and how long it can dispel the feeling of hunger) in comparison with two commercial snack bars.

The glycaemic response to a food is a measure of the impact of a carbohydrate food on blood glucose concentration. A lower glycaemic index (GI) food will produce a lower peak concentration of blood glucose but will continue to maintain blood glucose for a

sustained period, whereas a high GI food will produce a higher peak of glucose concentration in the blood but over a lesser time period.

It is known that keeping blood glucose stable and eating foods that suppress hunger and promote satiety have beneficial impacts for health. Therefore a food with reduced glycaemic effect and higher satiety is considered a healthier option.

How was I identified and why am I being invited to participate in this research?

I am seeking 26 volunteers to take part in the research project on AUT South campus and North Shore campus, and have been advertising the research on noticeboards on AUT campuses.

If you are 50 or older, do not have type 1 or 2 diabetes mellitus, allergies to nuts, gluten, egg or any condition that might prevent you from providing a small blood sample, your participation would be most welcome.

What will happen in this research?

If you choose to participate please contact me. I will arrange to meet you to discuss the details of the project. After that if you would like to volunteer to participate you will be asked to sign a consent form and I will arrange a time for you to attend the laboratory for the first of the three testing visits. Each visit will take two and a half hours with a start time of about 8:00 am and a finish time of about 10:30 am. The start time can vary to suits your schedule if necessary.

On the first visit you will be asked to provide some personal information (contact details, date of birth, ethnicity, and gender) and your height and weight will be measured.

The procedure of the testing visit follows:

- Arrive in the morning (about 8:00 am) after 10 to 12 hours overnight fast. This means you stop eating any food or drink (other than water) from 10:00 pm the night before.
- No exercise on the day before the testing.
- On your arrival your finger will be pricked twice five minutes apart to measure your fasting blood glucose concentration.
- You will then be given a snack bar to eat and be required to remain seated and relaxed for the next two hours. You can read, talk, use your computer, etc. You can bring a friend to talk if you want to, but you must remain calm.
- To measure the increase and subsequent decrease in your blood glucose concentration as a result of the snack bar, we will collect a single drop of blood from you by finger-prick at 15, 30, 45, 60, 90 and 120 minutes. If your blood glucose reading has not come down to baseline by two hours, we would ask you to remain seated and undergo two further blood glucose tests at 150 and 180 minutes.
- As part of the satiety evaluation, you will be asked how hungry you feel after each blood sample.
- On the second and third visits you will be given a different snack bar to eat. The same blood sampling and questioning routine will be followed as for the first test.

At the end of each of these three visits, you will be given breakfast of cereals and fruit and at the completion of the third of the three visits you will receive a $60 petrol voucher to cover your travel expenses.

At all times you may ask questions. Please be aware that you may decide at any time to stop taking part in the project without any disadvantage to yourself of any kind.

What are the discomforts and risks? How will these discomforts and risks be alleviated?

Minor discomfort may result from overnight fasting and the finger pricks. You will be provided with a light breakfast at the end of the procedure and you may drink water at any time.

What are the benefits?

The information obtained will help understanding the glycaemic index and satiety advantages, if any, of the newly developed snack bar compared with similar commercial snack bars. Further the results will be used for my PhD thesis and might also form the basis of a health claim for the snack bar should it become a commercial reality.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

Personal identifying information will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for six years and then destroyed. This will ensure your privacy and anonymity. All uses of data in reports, journal articles, and conference papers will be summary data so that you would not be identifiable in any way.

What are the costs of participating in this research?

Four visits to the laboratory are required on four separate days. The first one is for half an hour maximum to discuss the project and show you what is required. The next three visits of two and a half hours each are required and you must not have eaten since 10pm on the day prior to these visits. You will be reimbursed $60 for travel expenses at the conclusion and given a light breakfast each time.

What opportunity do I have to consider this invitation? How do I agree to participate in this research?

After you have read this information sheet and if you would like to participate contact me to make an appointment to discuss the project in more details. If after that you agree to participate you will be asked to sign a consent form and to arrange a time for the first of your three testing visits. You may ask questions at any time and withdraw from the project without any disadvantage at any time.

You have two weeks in which to consider whether or not you wish to take part in this research.

Will I receive feedback on the results of this research?

At the end of the study, you will receive a copy of the report of this study. The results of the project may be published and will be available at AUT University (Auckland, New Zealand).

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Professor Elaine Rush, elaine.rush@aut.ac.nz AUT University, Phone 021 624 077

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, ethics@aut.ac.nz , 09 921 9999 ext 6038.

Whom do I contact for further information about this research?

Researcher Contact Details:

Mary Yan, myan@unitec.ac.nz, Phone 021 044 1561

Project Supervisors Contact Details:

Professor Elaine Rush, AUT University, Phone 021 624 077

Approved by the Auckland University of Technology Ethics Committee

AUTEC Reference number *14/342*.

Participant Information Sheet

Project Title:

Glycaemic impact of consumption of the Nothing Else healthier snack bar

An Invitation

Hi, my name is Mary Yan, a PhD student in the School of Sport & Recreation at AUT University. I would like to invite you to participate in a research project, which involves investigating the glycaemic impact of consumption of the Nothing Else healthier snack bar in a 13-week trial.

Thirty volunteers are required for the study, which will be conducted at UNITEC Mt Albert campus.

Please read this information sheet carefully before deciding whether or not to volunteer. If you decide you would like to participate please contact me. The contact details are shown below. If you decide not to take part there will be no disadvantage to you and I thank you for considering my request.

What is the purpose of this research?

The study is designed to investigate the long term glycaemic impact of consumption of Nothing Else snack bar, and what is the influence on eating behaviour, snack food choice and snacking frequency.

The Nothing Else bar is a newly developed healthier low glycaemic index (GI) snack bar. The GI is a measure of the increase in glucose concentration in the blood after consumption of a carbohydrate food. A low GI food will produce a lower peak concentration of blood glucose but will continue to produce it for a sustained period,

whereas a high GI food will produce a higher peak of glucose concentration in the blood for a longer time.

The beneficial effects of low GI diets have been documented by improved blood glucose control, lowered HbA1c (a long term measure of glucose control) and improved glucose tolerance and insulin sensitivity. Therefore a food with reduced glycaemic impact is considered a healthier option.

How was I identified and why am I being invited to participate in this research?

We are seeking 30 volunteers to take part in the research project on UNITEC campuses and have been advertising the research on noticeboards around the campus and on the campus intranet. This information sheet is available from the researcher.

If you are 50 or older and are regular snack bar consumers, do not have type 1 or 2 diabetes mellitus, allergies to nuts, gluten, egg or any condition that might prevent you from providing a small blood sample, and furthermore, can commit to the 12 week requirement of the trial, your participation would be most welcome.

What will happen in this research?

If you choose to participate please contact the researcher who will arrange to meet you to discuss the details of the project. After that if you would like to volunteer to participate you will be asked to sign a consent form and the researcher will allocate a time for you to start the intervention. This is a 12-week trial, so think about carefully before you decide to participant.

On the first visit you will be asked to provide some personal information (contact details, date of birth, ethnicity, and gender) and your height and weight will be measured.

The protocol of the trial follows:

You will be assigned randomly (one in two possibilities) to receive the snack bar free of charge for 6 weeks – either at 0 or 6 weeks. Once you start receiving the snack bar (delivered weekly), you will be asked to consume the Nothing Else bar each day as the main snack choice for six weeks. You can still eat fruits. In the control period, there should be no changes in your normal diet.

Finger prick HbA1c will be tested twice (a week apart) before the trial starts to set up the baseline, then four times at the time point of week 4, 6, 10, and 12 weeks respectively.

You will be asked at 0, 6 and 12 weeks to complete a dietary habits questionnaire concerning dietary snack habits, how often you consume sugary drinks or sugary foods, how often and how much you eat foods such as rice or white bread.

A snacking diary will be provided to record any changes in your eating behaviour and time of snacking daily, also to score feeling of fullness on scales after eating a snack.

Researcher will visit you to collect the diary and deliver the Nothing Else bars on a weekly basis. Enough Nothing Else bars will be supplied if you want to have more than one bar a day.

In total the duration of the trial will be 12 weeks.

At all times you may ask questions. Please be aware that you may decide at any time not to take part in the project without any disadvantage to yourself of any kind.

What are the discomforts and risks? How will these discomforts and risks be alleviated?

Minor discomfort may result from the finger pricks. So potential participants will be introduced to the process in the information meeting prior to volunteering to participate in the study so will be well aware of the level of discomfort involved.

What are the benefits?

The information obtained will help understanding if the newly developed healthy snack bar has beneficial effects on long term glycaemic control with improved HbA1c. Furthermore the results will be used by the researcher in her PhD thesis and might also form the basis of a health claim for a commercial snack bar. Commercialisation is managed by the AUT University research and innovation office as part of a larger project.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

Personal identifying information will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for six years and then destroyed. This will ensure your privacy and anonymity. All uses of data in reports, journal articles, and conference papers will be summary data so that you will not be identifiable in any way.

What are the costs of participating in this research?

The researcher will visit you to collect the diary and deliver the Nothing Else bar (if it is your turn to receive the bar) on a weekly basis. The bars will be provided to you free of charge for six weeks. The cost of participating in this research is your time to fill the snacking diary.

What opportunity do I have to consider this invitation? How do I agree to participate in this research?

When you have read this information sheet if you would like to participate contact the Researcher to make an appointment to discuss the project in more details. After that if you agree to volunteer to participate you will be asked to sign a consent form. You may ask questions at any time and withdraw from the project without any disadvantage at any time.

Will I receive feedback on the results of this research?

At the end of the study, you will receive a copy of the report of this study. The results of the project may be published and will be available in the AUT University (Auckland, New Zealand).

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Professor Elaine Rush, elaine.rush@aut.ac.nz AUT University, Phone 021 624 077

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, ethics@aut.ac.nz , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Researcher Contact Details:

Mary Yan, mary.yan@aut.ac.nz, Phone 021 044 1561

Project Supervisor Contact Details:

Professor Elaine Rush, AUT University, Phone 021 624 077

Professor Gillian Whalley, Unitec Institute of Technology, Phone 021 306 509

Approved by the Auckland University of Technology Ethics Committee
AUTEC Reference number 14/379.

Appendix D. Informed Consent Forms

Consent Form

Project title: **Nothing Else: A Healthier Snack Bar**

Project Supervisor: **Professor Elaine Rush**

Researcher: **Mary Yan**

- ○ I have read and understood the information provided about this research project in the Information Sheet.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ I have discussed with the researcher **any** known allergies to food ingredients, e.g. nuts, gluten, egg, milk, and colours which may exclude me from this study.
- ○ I agree to take part in this research.
- ○ I agree to consume the snack bar samples and provide my preferences for liking of the colour, texture, flavour, sweetness and my liking for the packaging.
- ○ I am at least 18 years old.
- ○ I wish to receive a copy of the report from the research (please tick one) by email or post (Please provide contact details below)

Participant's signature:

.....……

Participant's Name:

.....……

Participant's Contact Details (Email or Post):

……

……

……

Date:……

Approved by the Auckland University of Technology Ethics Committee on 19 November 2013, AUTEC Reference number 13/184.

Note: The Participant should retain a copy of this form.

Consent Form

Project title: **Glycaemic Response and Satiety Effect of Snack Bars**

Project Supervisor: **Professor Elaine Rush**

Researcher: **Mary Yan**

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 8 October 2014.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ I have discussed with the researcher any known allergies to food ingredients, e.g. nuts, gluten, egg, milk; and my health conditions which may exclude me from this study.
- ○ I agree to take part in this research.
- ○ I agree to consume the snack bar samples and provide a small blood samples by finger-prick. No blood samples from the finger-prick will be retained – it will be disposed of using standard disposal methods immediately after the blood glucose concentration has been recorded.
- ○ I wish to receive a copy of the report from the research (please tick one) by email or post (Please provide contact details below)

Participant's signature:

.....……

Participant's Name:

.....……

Participant's Contact Details (Email or Post):

……

……

Date:……

Approved by the Auckland University of Technology Ethics Committee on 25 November 2014. AUTEC Reference number 14/342.

Note: The Participant should retain a copy of this form.

Consent Form

Project title: **Glycaemic impact of consumption of the Nothing Else healthier snack bar**

Project Supervisor: **Professor Elaine Rush**

Researcher: **Mary Yan**

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 30 October 2014.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ I have discussed with the researcher any known allergies to food ingredients, e.g. nuts, gluten, egg, milk; and my health conditions which may exclude me from this study.
- ○ I agree to consume the Nothing Else snack bar for six weeks and provide a small blood samples by finger-prick at the required time points. No blood samples from the finger-prick will be retained – it will be disposed of using standard disposal methods immediately once the blood sample has been tested.
- ○ I understand that I will be randomised to receive the Nothing Else bar either in the first or second six week period of the study.
- ○ I wish to receive a copy of the report from the research (please tick one) by email or post (Please provide contact details below)

Participant's signature:

.....

Participant's Name:

.....

Participant's Contact Details (Email or Post):

……

……

Date:……

Approved by the Auckland University of Technology Ethics Committee on 17 December 2014. AUTEC Reference number 14/379.

Note: The Participant should retain a copy of this form.

Appendix E. Nutrition information of the Nothing Else prototype compared with that of commercially available snack bars in the New Zealand market

	Nutrition information average quantity per 100g											
Product	Energy (kJ)	Protein (g)	Saturated fat (g)	Sugars (g)	Sodium (mg)	NSP fibre (g)	Fruit, veg & nut (%)	Nutrition score	Revised* score	Weight (g)/bar	Cost ($) /bar as at July 2013	Cost ($) /g protein
Nothing Else bar	1461	13.4	1.59	16.1	60	9.3	36.6	-1	-1	80[1]	2[2]	0.19
Sanitarium apricot bites	1430	8.9	0.3	21.4	285	9	4.5	1	6			
Superfruits cranberry & blueberry bar	1520	6.9	2.8	29.5	57	5	45	2	6	30	0.5	0.24
Moonbar	1990	16	3.8	30.6	16	6.9	50	3	8			
Cranberry Almond kind bar	1990	10	3.0	27.0	50	7.5	50	3	8	40	2.8	0.72
One Sqare Meal bites	1660	9.5	4.6	17.1	292	5.7	12	4	9	45	1.1	0.27
Nice ‘n’ natural almond nut bar	1950	14.4	4.9	30.4	50	5	49	4	9	32	0.5	0.24
Nice ‘n’ natural apricot muesli bar	1760	9.6	5.1	21.2	56	6.4	26	4	9			
Weightwatchers almond & apricot bar	1860	8.6	5.0	25.1	91	5.2	45	5	10	34	1	0.34
Nature valley crunchy oats & honey	1902	8.0	1.7	27.8	350	5.0	0	5	10	42	0.7	0.21
Nature Valley Crunchy Apple Crisp	1876	8.1	1.7	28.9	354	6.1	2	5	10	42	0.7	0.21
Brekkie cashew & cranberry muesli bites	1759	11.5	4.2	25.6	175	8	32	5	10	45	1	0.48
Nice ‘n’ natural almond nut bar	1910	11.8	5.0	31.8	235	5	55	6	11	32	0.5	0.25
Nature valley crunchy roasted almond	1983	9.1	2	24.8	406	4.6	5	6	11	42	0.7	0.18
Tasti nut bar almond	2160	14.2	6.7	23.8	25	5.5	58	6	11	35	0.65	0.13
Tasti yoghurt fruit & nut bar	2040	12.5	6.8	29.7	22	4.6	57	7	12	30	0.65	0.15
Nice ‘n’ natural almond nut bar yoghurt	2120	16.2	7.3	27.9	41	5.3	62.5	7	12			

Product	Nutrition information average quantity per 100g											
	Energy (kJ)	Protein (g)	Saturated fat (g)	Sugars (g)	Sodium (mg)	NSP fibre (g)	Fruit, veg & nut (%)	Nutrition score	Revised* score	Weight (g)/bar	Cost ($) /bar as at July 2013	Cost ($) /g protein
Nice 'n' natural yoghurt muesli bar	1880	10.3	9	24.4	68	5	17.5	9	13			
Flemings apricot choc chip muesli bar	1670	6.1	8.6	25.3	95	7.2	3	10	13	30	0.45	0.25
Mother earth date pudding slices	1610	6.5	7.4	35.8	217	4.8	18	11	15			
Bumper bar	1840	6.0	16.2	27.1	103	7.9	12	13	16	75	2	0.44
Mother earth Oaty slices	1840	7.1	10.9	27.5	222	3.9	6	13	17	40	0.67	0.23
Mother earth sultana, oat & honey slices	1630	6.3	8.7	37.8	310	5.6	31	15	18			
Cadbury brunch mixed berry bar	1810	4.5	8.4	34.8	189	0	50	19	21	35	0.7	0.44
Cadbury brunch fruit & nut bar	1890	5.2	9.4	35.5	179	0	11	19	22	35	0.7	0.40

*If a food or drink scores 11 or more points for energy, saturated fat, sugar and sodium then it cannot score points for protein unless it also scores 5 points for fruit, veg and nuts.

[1] suggested weight/bar, [2] suggested price

Appendix F. Testing Procedure of Blind and Unblinded Sensory Trials

Participants arrive at the sensory laboratory

↓

Participants are guided to sit at different tables

↓

Participants sign the consent forms

↓

The research explains the testing procedure to participants

↓

Six questionnaires to be provided to participants

↓

Six samples to be provided to participants

↓

Participants start the blind testing

↓

The researcher collects the questionnaires once participants complete the tasks of step one

↓

Five questionnaires to be provided to participants

↓

Five samples to be provided with the front and back packs to participants

↓

Participants start the branded testing

↓

The researcher collects the questionnaires once participants complete the tasks of step two

Appendix G. Individual glycaemic responses to the three test snack bars

	Individual glycaemic responses to the NE bar (mmol/L)						
Interval (min)	0	15	30	45	60	90	120
Participant							
1	4.25	5.2	5.8	6.6	5.8	4.7	4.4
2	5.7	6.0	7.5	7.4	6.9	5.6	6.2
3	5.1	5.3	6.3	6.5	5.6	5.1	4.8
4	4.3	5.2	5.3	6.0	6.5	5.7	4.7
5	5.05	5.5	6.9	8.1	7.3	6.0	5.4
6	4.9	5.0	5.8	6.3	5.9	4.6	4.9
7	5.0	5.0	5.3	5.5	5.6	5.0	5.0
8	4.65	6.1	7.5	8.1	6.7	5.3	4.8
9	5.1	5.6	6.2	6.9	6.4	5.7	5.2
10	4.45	5.2	6.0	6.2	5.8	4.9	4.8
11	5.15	5.0	6.3	6.4	6.2	5.6	5.2
12	5.15	5.6	5.4	6.3	6.5	5.5	5.2
13	4.75	5.2	5.8	6.1	5.5	5.2	5.2
14	5.15	5.0	5.8	6.0	6.1	5.6	5.3
15	5.35	5.5	6.1	7.2	6.7	6.9	5.2
16	5.55	6.2	7.4	7.7	5.7	5.1	5.3
17	4.9	5.4	5.3	6.3	6.1	5.3	4.4
18	5.2	7.0	7.5	6.7	5.5	5.2	5.6
19	5.9	6.6	5.6	5.8	7.1	5.3	5.5
20	4.6	5.0	6.1	5.8	5.6	5.1	4.8
21	5.15	6.3	6.2	6.7	7.1	5.3	4.7
22	5.1	5.9	6.1	7.1	6.3	4.3	4.9
23	5.85	6.9	7.0	7.1	7.5	6.4	5.9
24	4.6	5.9	5.6	5.8	6.6	5.0	4.6

	Individual glycaemic responses to Bar 1 (mmol/L)						
Interval (min)	0	15	30	45	60	90	120
Participant							
1	4.05	5.4	5.6	5.7	4.8	4.2	4.5
2	5.4	6.5	7.5	8.2	6.8	5.8	5.1
3	5.25	6.1	8.7	6.3	6.9	6.2	5.1
4	4.45	4.6	5.7	5.3	4.8	4.5	4.4
5	5.3	5.9	7.0	6.8	6.8	5.2	5.3
6	4.45	5.4	5.9	6.1	5.5	4.8	4.5
7	4.6	5.0	6.0	6.0	5.1	5.2	4.8
8	4.55	5.2	8.1	6.3	5.3	5.3	4.8
9	5.65	6.0	6.9	6.5	5.2	5.5	5.7
10	5.55	6.5	6.6	6.2	5.7	5.6	4.9
11	5.75	6.4	8.1	7.0	6.3	5.3	5.5
12	5.2	5.7	6.2	6.4	6.3	5.4	5.7
13	4.6	5.6	6.1	5.8	5.8	5.4	5.5
14	5.05	5.3	5.8	6.2	6.3	5.3	5.3
15	5.5	5.7	6.9	6.6	5.5	4.8	5.3
16	4.9	6.3	8.1	6.9	6.0	4.9	5.6
17	5.6	5.5	5.8	7.2	5.8	5.6	6.2
18	4.5	5.7	6.3	6.1	5.3	5.1	4.8
19	5.0	5.2	5.5	5.5	5.8	5.0	4.8
20	4.65	5.3	6.1	6.0	5.8	5.3	5.0
21	4.9	5.5	7.7	6.9	6.0	4.9	5.0
22	5.35	5.7	7.1	7.2	6.5	5.1	5.2
23	5.35	5.9	6.9	7.5	7.1	6.0	5.7
24	4.4	4.2	6.4	6.4	4.9	4.7	4.6

	Individual glycaemic responses to Bar 2 (mmol/L)						
Interval (min)	0	15	30	45	60	90	120
Participant							
1	4.7	4.7	6.5	6.0	5.8	5.2	4.3
2	5.65	6.5	8.2	8.2	6.4	5.5	5.1
3	5.2	6.4	7.5	7.3	6.0	5.3	5.0
4	4.95	5.1	6.1	6.1	6.0	5.3	4.7
5	5.8	7.0	7.7	8.9	9.0	7.2	6.7
6	4.6	4.5	4.7	6.1	6.7	6.4	4.8
7	4.65	5.4	6.2	5.5	5.0	4.9	5.0
8	5.2	5.5	8.2	9.2	8.2	6.2	5.4
9	5.8	6.0	7.5	7.7	7.6	6.8	6.1
10	5.3	6.5	7.8	7.7	6.8	5.7	4.4
11	6.0	6.9	8.1	7.5	6.5	5.6	4.9
12	5.5	6.3	7.4	7.2	7.5	5.4	5.1
13	5.4	5.4	7.0	6.9	6.2	4.9	4.4
14	5.15	5.6	6.9	6.8	6.2	5.5	4.9
15	5.35	6.1	7.4	8.4	6.7	5.0	4.5
16	4.9	5.5	7.3	7.6	6.9	5.5	5.8
17	4.8	5.2	5.8	6.9	7.2	5.0	4.6
18	5.4	6.7	8.5	7.9	7.4	5.1	5.2
19	4.75	5.4	6.7	6.7	6.3	5.4	5.5
20	4.95	5.6	7.2	7.0	6.1	5.0	4.7
21	4.65	5.1	5.9	7.4	7.1	6.2	5.3
22	4.7	5.8	6.9	6.4	6.0	5.0	4.6
23	5.6	6.8	7.1	6.8	8.3	7.5	5.8
24	4.65	5.7	6.7	7.4	5.8	5.3	4.3

Appendix H. Abstracts of Experimental Chapters from Journal Articles Formatted for Submission

I

Branding, Ingredients and Nutrition Information: Consumer Liking of a Healthier Snack

M. R. Yan, D. Brown, A. Parsons, G. A. Whalley, N. Hamid, K. Kantono, B. Donaldson & E. Rush. (2015). *Journal of Food Research*; 4:64-72. doi:10.5539/jfr.v4n5p64

Abstract

Taste appeal, sustainable ingredients and valid health claims are challenges for successful marketing of healthier food products. This study was designed to compare the effects of branding, ingredients and nutrition information on consumer liking towards a prototype of the Nothing Else healthier snack bar with the top three brands of New Zealand snack bars, and another product with a good nutrient profiling score. Sixty-four consumers were recruited to evaluate the five snack bars. Participants initially blind-rated on visual analogue scales their liking scores in relation to colour, taste, flavour, texture and overall liking. Packaging for the products was then presented alongside each of the five products and participants rated their liking scores for a second time. Participants also ranked the five products from 1 to 5 for healthiness, taste, naturalness, and purchase intent if prices were the same. In both blind and informed tests, the Nothing Else bar was the least liked snack bar among all the tested samples. However, after the packaging for the products was presented, overall liking of the Nothing Else bar increased by 14% (p = 0.023), while overall liking for the four commercial products were unchanged. While the most popular commercial bar was ranked the highest for taste and purchase intent, the Nothing Else bar was ranked the highest for the healthiness and naturalness. Our findings confirmed that the branding and health related nutrition information could improve consumer liking and brand perception particularly if backed by marketing.

Keywords: brand perception, healthier snacking, Nothing Else, sensory properties

II

Snack Bar Composition and Their Acute Glycaemic and Satiety Effects

M. R. Yan, A. Parsons, G. A. Whalley, J. Kelleher & E. C. Rush. (2017). *Asia Pacific Journal of Clinical Nutrition*; 26(4). doi:10.6133/apjcn.072016.04

Abstract

Background and objectives: Maintaining blood glucose within homeostatic limits and eating foods that suppress hunger and promote satiety have beneficial impacts for health. This study investigated the glycaemic response and satiety effects of a serving size of a healthier snack bar, branded Nothing Else that met the required nutrient profiling score criteria for a health claim, in comparison to two top-selling commercial snack bars. ***Methods and study design:*** In an experimental study, 24 participants aged ≥ 50 years were recruited. On three different days, blood glucose concentration was measured twice at baseline and 15, 30, 45, 60, 90 and 120 minutes after consumption of a serving size of each bar. Satiety effects were self-reported hunger, fullness, desire to eat, and amount could eat ratings on visual analogue scales. ***Results:*** The incremental area under the blood glucose response curve (iAUC) over two hours for the Nothing Else bar was 30% lower than commercial Bar 2 ($p < 0.001$). At 45 minutes after eating, the Nothing Else bar induced the highest fullness rating and lowest hunger rating among the three snack bars. At two hours, fullness induced by the Nothing Else bar was twice that of Bar 2 ($p = 0.019$), but not different to Bar 1 ($p = 0.212$). ***Conclusion:*** The Nothing Else snack bar developed using the nutrient profiling scheme as a guideline, with its high protein and dietary fibre contents, had a lower glycaemic impact and induced a higher subjective satiety than the two commercial snack bars of equal weight.

Keywords: macronutrient, nutrient profiling, glycaemic response, hunger, satiety

III

Effects of a Healthier Snack on Snacking Habits and Glycated Hb (HbA1c): A 6-Week Intervention Study

M. R. Yan, A. Parsons, G. A. Whalley & E. C. Rush. (2017). *British Journal of Nutrition*; doi:10.1017/S0007114516004372

Abstract

Dietary behaviour modification may change eating habits and reduce the impact of poor nutrition. This study aimed to evaluate the effects of daily consumption of a healthier snack bar on snacking habits and HbA1c within a 6-week intervention. Twenty-eight participants were randomly allocated to two groups to either consume the bar as the main snack for 6 weeks (*n* 14) or receipt of the bars was delayed for 6 weeks (*n* 14) following a stepped wedge design. All participants had HbA1c measured at weeks -1, 0, 4, 6, 10, and 12. A short dietary habits questionnaire was self-completed at weeks 0, 6, and 12. Participants consumed the bars they received instead of other snacks and found the healthier snack was acceptable as part of their daily dietary pattern. Over the 12 weeks, there was a significant reduction in intake of biscuits, cakes and pies (~2 servings/week, $p < 0.05$) in both groups. Fruit juice intake was reduced (~1 serving/week, $p = 0.029$) in the first group. Twenty participants (71.4%) experienced a decrease (*n* 15) or no change (*n* 5) in HbA1c (range 0-4 mmol/mol); while eight participants experienced an increase in HbA1c (range 0.5-2.5 mmol/mol). There was high compliance with the healthier snack intervention and a trend toward a favourable effect on glucose homeostasis. Habitual snacking behaviour has the potential to be improved through changes in the food supply and in the longer term may reduce the impact of poor nutrition on public health.

Keywords: dietary behaviour: glycaemic impact: HbA1c: intervention: snacking

Appendix I: Letters seeking permission from publishers

Mary Yan

Auckland University of Technology

Auckland, New Zealand

2 August 2016

Journal of Food Research

Dear Prof Antonello Santini,

I am the lead author of *Branding, ingredients and nutrition information: consumer liking of a healthier snack* (''the Work'') which was published by *Canadian Centre of Science and Education* in *Journal of Food Research* in August 2015 and for which the copyright was assigned to your company.

I am a doctoral student at Auckland University of Technology and would like to include the Work in my doctoral thesis 'Nothing Else: A Healthier snack'. The Work would be fully and correctly referenced in this thesis.

A print copy of this thesis when completed will be deposited in the Auckland University of Technology Library, and a digital copy will also be made available online via the University's digital repository, Scholarly Commons http://autresearchgateway.ac.nz/. This is a not-for-profit research repository for scholarly work which is intended to make research undertaken in the University available to as wide an audience as possible.

I would be grateful if you, or the company you represent, could grant me permission to include the Work in my thesis and to use the Work, as set out above, royalty free in perpetuity.

If you agree, I should be very grateful if you would sign the form below and return a copy to me. If you do not agree would you please notify me of this. I can most quickly be reached by email at maryan@aut.ac.nz.

Thank you for your assistance. I look forward to hearing from you.

Yours sincerely

Mary Yan

I/We Bella Dong hereby grant permission for use of the Work for the purposes and the terms identified above.

For and on behalf of CANADIAN CENTER OF SCIENCE AND EDUCATION

Date: 3 August 2016

Mary Yan

Auckland University of Technology

Auckland, New Zealand

3 August 2016

Asia Pacific Journal of Clinical Nutrition

Dear Editor,

I am the lead author of *Snack bar composition and their acute glycaemic and satiety effects* (''the Work'') which was published by The HEC Press in *Asia Pacific Journal of Clinical Nutrition* in *APJCN Vol 26 Issue 4* and for which the copyright was assigned to your company.

I am a doctoral student at Auckland University of Technology and would like to include the Work in my doctoral thesis 'Nothing Else: A Healthier snack'. The Work would be fully and correctly referenced in this thesis.

A print copy of this thesis when completed will be deposited in the Auckland University of Technology Library, and a digital copy will also be made available online via the University's digital repository, Scholarly Commons http://autresearchgateway.ac.nz/ . This is a not-for-profit research repository for scholarly work which is intended to make research undertaken in the University available to as wide an audience as possible.

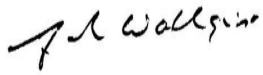
I would be grateful if you, or the company you represent, could grant me permission to include the Work in my thesis and to use the Work, as set out above, royalty free in perpetuity.

If you agree, I should be very grateful if you would sign the form below and return a copy to me. If you do not agree would you please notify me of this. I can most quickly be reached by email at maryan@aut.ac.nz.

Thank you for your assistance. I look forward to hearing from you.

Yours sincerely

Mary Yan

I/We  hereby grant permission for use of the Work for the purposes and the terms identified above.

For and on behalf of The HEC Press (*Asia Pacific Journal of Clinical Nutrition*)

Date: 4 August 2016