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A Preliminary Assessment of the Glycemic Index of Honey

A report for the Rural Industries Research and Development Corporation

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Foreword

In recent years scientists have been investigating the physiological responses (effect on blood sugar levels) to food, particularly the effects of different carbohydrate containing foods. Honey has been classified to be a food containing simple sugars and this has several implications on the choice of foods for diabetics.

Glycemic Index factor is a ranking of foods based on their overall effects on blood sugar levels. The source of honey decided the sugar and acid composition of honey which can show differences in the GI factor. Little or no information exists on the GI of honey and in particular no information exists on the differences in the GI of different honey varieties.

The quantitative measurement of organic acid and carbohydrate composition of different floral varieties would therefore enable the study of GI of honey, and lead the way to understanding whether or not all types of honey should be classified as one type of food for people with Diabetes.

RIRDC has been able to facilitate this study by providing the funding for this project. This report discusses the sugar and acid composition of six floral varieties of honey, namely Red Gum, Salvation Jane, Ironbark, Yellow Box, Stringybark and Yapunyah and two commercial blends obtained in 2001, and their effects on the blood glucose response in humans.

This report is presented in a convenient format ready to publish in industry journals thus ensuring that the beekeepers benefit from the findings of the study.

This project was funded from industry revenue which is matched by funds provided by the Federal Government.

This report, a new addition to RIRDC's diverse range of over 1200 research publications, forms part of our Honeybee R&D program, which aims to improve the productivity and profitability of the Australian Beekeeping Industry.

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Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

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Susanna Holt (University of Sydney)

Abbreviations

GI	Glycemic Index
II	Insulin Index

Contents

Executive Summary

Objective

To obtain a clear understanding of the differences between the blood glucose responses of the different sources of honey based on sugar and organic acid contents and identify those varieties with low GI factor to use as a major marketing strategy to increase consumption, especially in Diabetics.

Method

Initial discussions with the Department of Agriculture, NSW were held to identify the common floral varieties of honey that were available in 2001 depending on the season. The relevant suppliers in Queensland, NSW, South Australia and Western Australia were approached for the supply of honey with floral authentication. Six floral varieties namely, *Red Gum (E. camaldulensis)*, *Salvation Jane (Echium lycopsis)*, *Ironbark (E. nubilis)*, *Yellow Box (E. melliodora)*, *Stringybark (E. macrorhyncha)* and *Yapunyah* (*E. ochrophloia)* and two commercial blends were obtained from the above suppliers.

When the samples were received in the laboratory, they were stored at -18^0C until further analyses. Samples were analysed for their sugar contents, namely, fructose, glucose, maltose and sucrose and organic acids using standard HPLC techniques; and pH. The samples were tested for Glycemic Index and Insulin Index through a human study comprising at least 10 healthy individuals. Glycemic Index is a method developed in order to rank equal portions of different foods according to the extent to which they increase blood glucose levels after being eaten. On the basis of the available carbohydrate (sugars) content of the honeys, an amount of honey containing 25 grams of carbohydrate was given to each volunteer to eat after an overnight fast. Over the next two hours, finger prick capillary blood samples were collected and compared similarly with a reference food namely 25g bread. The Insulin Index was also studied using the same procedure in the same subjects except that the concentration of insulin in the plasma component was analysed instead.

Results and Discussion

The major results from the study are that:

- There were a lot of differences in the physical form of the honeys. Some were more solid and crystallised and others were more fluid.
- The fructose contents varied from 27.5 – 52.4 g/100g of the honey amongst the varieties studied with a commercial blend (1) having the lowest and *Stringybark* having the highest.
- The glucose contents varied from 20.3 – 32.9 g/100g with the same commercial blend (1) having the least but the *Red gum* variety having the highest.
- Glucose and fructose were the predominant sugars found in all the honeys tested.
- Malic and succinic acids were the predominant organic acids found in all the varieties. Total acid content was lowest in the commercial blend (1) and highest in *Stringybark*
- The pH of the honeys revealed that the range was between 5.2 (*Salvation Jane*) and 6.4 (*Iron Bark*).
- *Yellow Box, Stringybark , Red Gum, Iron Bark* and *Yapunyah* honeys were considered to be of low GI. Hence these are more suitable for consumption in controlled amounts by people with diabetes and other health problems associated with poor blood glucose control (eg. pancreatic disease, polycystic ovarian syndrome). The commercial blend (1) and *Salvation Jane* honeys are of moderate GI and Commercial blend (2) was considered to be a high GI food. The insulin responses were not exaggerated in relation to their corresponding glycemic responses. Therefore the eight honeys tested do not appear to contain any insulinogenic components, other than sugar.

- Only the honey's fructose content was significantly associated with the average GI values and average II values. The other individual sugars were not significantly associated with either the GI or the II values.

Outcomes

The results of this study showed that different honeys could have significantly different effects on blood glucose and insulin levels, due to differences in their sugar content and physical form, and should not all be classified as one type of food for people with diabetes.

Now armed with the knowledge that there are differences in the GI between the floral varieties of honey, and the fact that *Yellow Box, Stringybark , Red Gum, Iron Bark* and *Yapunyah* honeys were considered to be of low GI and *Salvation Jane* and a commercial blend (1) were of moderate GI, it should now be possible to better market these honeys as suitable for consumption in controlled amounts for the diabetics. Commercial blends may vary in their composition depending on the availability of honeys in that particular season and hence should be treated with caution if the varieties that have gone into the blend are unknown as GI will be variable too. From the consumers' point of view, the floral varieties identified above with low to moderate GI should ideally be produced more and marketed better by the Honey Industry. There may be other floral varieties that may be available which should be studied in future for their GI.

1. Introduction

Honey is the natural sweet substance produced by *Apis mellifera* bees from the nectar of plants or from secretions of living parts of plants or excretions of plant sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in the honey comb to ripen and mature (Codex standard, 1987).

Honey has a health attribute of being a readily available energy source. The overall health effect of honey on individuals is often equated by health professionals with table sugar since the total energy levels of white sugar and honey are quite similar. In addition total carbohydrates for honey and table sugar are high. Over 82% of the solids in honey are composed of sugars. Health professionals are often unaware of the types of carbohydrates in honey as compared to table sugar. Honey's major carbohydrates are the monosaccharides fructose and glucose while table sugar's major carbohydrate is sucrose, which is a disaccharide made up of glucose and fructose. The daily consumption of honey that might cause problems in people with diabetes would be very similar to the amount of sugar consumption that would supposedly cause a problem. Many diabetes associations in the world still put a cap on sugar consumption which is around 30g/day or 5% of the total energy intake. Since honey has high water content, an amount of 35-40g/day should be considered an upper limit of consumption.

Consequently there are differing physiological effects on blood sugar levels for honey as compared to table sugar. The blood glucose response is lower for honey compared to table sugar. The physiological effect of a carbohydrate on blood sugar levels is termed the Glycemic Index of the carbohydrate. The Glycemic Index of a food is the ranking of a food based on the glycemic effect compared with a standard food. The standard is usually bread or glucose.

The Glycemic Index of a food varies depending on factors such as processing methods and levels of organic acids. It has been used to classify carbohydrate foods for various applications, including health effects relating to diabetes, sports nutrition and weight management (Brand-Miller and Foster-Powell, K. 1999).

The Glycemic Index of Australian honey has been shown to be 58 (Brand-Miller, 1995). Only a limited number of studies worldwide have concentrated on the Glycemic Index of honey and these studies have looked at the Glycemic Index of blended honeys rather than individual honeys from different floral sources.

The aim of this research was to determine the Glycemic Index of six different Australian honey varieties and two commercial blends as available in the Australian market. The honey types were *Stringybark*, *Iron bark*, *Red gum*, *Salvation Jane*, *Yellow Box*, *Yapunyah* and two blended honeys. The honey types varied in composition depending on the floral sources from which the nectar and pollens were sourced. Honey was sourced from most Australian states. In addition to measuring the Glycemic Index, total sugars, types of sugars, total acids and types of acids were analysed for each honey type.

As a consequence of the study, an insight into the health effects, in relation to diabetes and sports nutrition, of the different types of honey was determined. It is anticipated that the image of honey to health professionals and sports persons will be improved. The Glycemic Index of the individual honey types can be further used as a marketing strategy to improve the saleability of honey.

2. Objectives

The objectives of this study were to:

- Analyse the total available carbohydrate and organic acid contents of six individual varieties and two blends of honey
- Assess the Glycemic index of the honeys in humans

3. Review of Literature

3.1 Honey

Honey has been described as a sweet viscous fluid made by honeybees from the nectar that they obtain from plants, mainly flowers. It is ready to be consumed as produced and is essentially a fructose solution supersaturated with glucose (White and Underwood, 1974).

In Australia honey is produced in most regions and approximately 75% of the Australian honey originates from natural Eucalypt forests.

Honey contains more than 180 identified substances but honey consists mainly of sugars with the remainder consisting of flavouring materials, minerals, acids, enzymes and pigments. The total amount of sugars and the relative amounts of the different sugars (sucrose, fructose and glucose) vary in nectars from different Eucalypts, and ultimately contribute to the different flavours and colours of honey (Rostaim Faraji-Haremi, 1976). The general composition and properties of honey are summarised in Tables 1 and 2.

Table 1. General composition of Australian honey

Composition	
Moisture	15 –18 (% w/w basis)
Fructose	36 – 50%
Dextrose (Glucose)	28 – 36%
Sucrose	0.8 – 5.0%
Maltose	1.7 – 11.8%
Nitrogen	0.05 – 0.38%
Ash	0.04 – 0.93%
pH	3.3 – 5.6
Enzymes	Invertase, diastase, glucose oxidase
Acid	0.5% (mainly Gluconic acid)
Free Acid	12 – 40 m-equiv./kg
Vitamins	Minimal, less than 10% of Australian RDI
Minerals	Minimal, less than 10% of Australian RDI

Source: Winner, 2001 (personal comm.)

Table 2. Physical properties of honey

Characteristic	**Value**
Specific gravity (17% moist 20^0C)	1.423
Viscosity (17.1% moist 25^0C)	150 poise
Specific heat (17.4% moist 20^0C)	2.26 kJ / kg / K
Thermal conductivity (17% moist 21^0C) (17% moist 71^0C)	 5.36×10^{-5} W/MK 5.95×10^{-5} W/MK
Freezing point (15%soln.)	-1.42 - -1.53^{0}C
Water activity (a_w)	0.5 – 0.6

Source: (D'arcy *et. al*., 1999)

Chandler *et. al.* (1974) performed chemical analysis of over 100 honeys from authenticated floral sources. Most samples were from commercial Australian honeys. The Australian sourced honeys came from all major honey-producing districts and represented over 60 different floral sources. Table 3 displays some representative floral sources from the different states and their corresponding composition. A more detailed composition of both pure single floral species honeys and blended honeys are available in Chandler *et. al*, (1974).

Table 3. Representative floral sources from Australian States (Chandler *et. al.* 1974)

Sample No.	Botanical Name	Local Name	Moisture (%)	pH	Total Acid (m-equiv/kg)	Total Sugars (%)	Fructose (%)	Glucose (%)	Sucrose (%)
New South Wales									
1	*E. camaldulensis*	River (red) gum	15.4	4.77	12.5	75.1	46.6	28.5	0.5
2	*E. macrorhyncha*	Red stringybark	16.5	4.44	17.7	74.0	44.0	30.0	2.0
3	*E. maculata*	Spotted gum	16.8	4.24	26.6	77.1	45.9	31.2	0.3
5	*E. melliodora*	Yellow box	15.8	4.05	20.3	76.2	49.2	27.0	2.0
8	*E. ochrophloia*	Napunyah	16.3	4.43	14.8	77.9	39.6	38.3	1.0
9	*E scabra*	White stringybark	14.9	4.58	6.8	66.1	45.9	20.2	11.6
12	*E. sideroxylon*	Mugga	15.7	4.17	16.1	75.5	45.2	30.3	2.0
15	*E. viridis*	Green mallee	14.3	4.54	9.0	75.9	45.7	30.2	2.5
85	*Echium lycopsis*	Paterson's curse	14.2	3.81	23.8	73.4	43.0	30.4	4.8
86	*Echium lycopsis*	Salvation Jane	15.5	3.80	23.1	76.4	43.1	33.3	2.2
Queensland									
17	*E. nubilis*	Dusky-leaved ironbark	17.4	4.48	10.0	74.8	44.4	30.4	1.4
20	*E. melliodora & E dealbata*	Yellow box & hill gum	13.6	4.50	17.4	72.0	44.6	27.4	0.1
South Australia									
22	*E. camaldulensis*	River (red) gum	15.3	4.02	19.3	74.3	40.5	33.8	0.9
26	*E. leucoxylon*	S.A. blue gum	15.5	3.99	21.3	76.6	43.6	33.0	1.5
Victoria									
34	*E. leucoxylon*	Yellow gum	15.3	4.10	20.7	70.3	40.2	30.1	5.7
Western Australia									
41	*E. marginata*	Jarrah	14.7	6.32	9.1	74.3	51.9	22.4	0.3
45	*E. calophylla & E. diversicolor*	Marri & Karri	15.0	5.18	10.7	73.7	43.7	30.0	1.2
Tasmania									
68	*Eucryphia lucida*	Leatherwood	15.9	4.90	11.6	73.5	44.5	29.0	3.7
70	*Eucryphia lucida*	Leatherwood	15.2	4.65	18.8	73.9	42.5	31.4	1.1

Honeys from the principal Australian floral source, the Eucalypts, show general uniformity in chemical composition with a light amber colour, low moisture content, low acid and high pH values, high glucose-to-moisture ratios and variable (low to high) granulation tendencies. Honeys from the floral sources, white *stringybark*, yellow gum and *yellow box* have higher sucrose content. Messmate honey has a high fructose and low glucose level, while *Yapunyah* has a high glucose and low fructose content. Honeys from non-eucalypt Australian species, mainly tea tree flora were darker in colour, higher in acidity (but not pH), higher in sucrose, and had a greater proportion of strong granulating tendencies. The acidity-pH-ash relationships for these honeys were abnormal and suggest the involvement of other factors besides acid and ash contents in determining the pH. Honeys from exotic floral sources such as ground flora with the exception of orange blossom, showed high granulation tendencies and low moisture contents. The honeys were lighter in colour (extra light amber), lower in ash and pH, and higher in acidity than eucalypt honeys (Chandler *et. al*, 1974).

3.1.1 Sugars of Honey

Honey is a carbohydrate with the sugars accounting for 82 – 85% of the solids content of honey. Since the sugars are the most important component of honey, the physical attributes of honey are largely determined by the kinds and concentrations of the carbohydrates present (Crane, 1976).

In most honeys, the monosaccharide fructose predominates but exceptions occur such as in rapeseed (canola) honey that contains greater amounts of glucose than fructose. There are at least twelve disaccharides in honey in addition to fructose and glucose. These are sucrose, maltose, isomaltose, nigerose, turanose, maltulose, leucrose, kojibiose, neotrehalase, gentiobiose, laminaribiose and isomaltulose (D'arcy *et. al.*, 1999).

3.1.2 Acids in Honey

The acids present in honey make up 0.5% of the total honey solids. The acids contribute to the flavours of honey. The organic acids reported to be present in honey include: gluconic, formic, acetic, butyric, lactic, oxalic, citric, succinic, tartaric, maleic, malic, pyroglutamic, pyruvic, α-ketoglutamic, glycolic, α or β glycerophosphate and glucose-6-phosphate (Crane, 1976). Not only do acid levels contribute to honey flavour, but the level of acidity of honey contributes to its' stability towards micro-organisms. Gluconic acid is present in honey in a higher amount than all other acids. It is produced by the action of an enzyme in honey on the glucose in it.

Except for gluconic acid, the sources of the various honey acids are not known. Many of the acids are intermediates in the Krebs cycle of biological oxidation, are of widespread occurrence and may be present already in the nectar.

The identification of gluconic acid in honey provides an explanation of a difficulty long encountered by analysts seeking to measure the total amount of the various acids in honey. This was done by titration with alkali, and an indistinct or fading endpoint is often encountered, which lead to uncertainty or error in the measurement. Gluconic acid exists in solution in equilibrium with its' lactone, or internal ester, which does not have an acid function.

3.1.3 Ash, Acidity and Ph

Standards for ash content are designed to reject honeys that have become contaminated by metal pickup from containers. There is a direct relationship between ash contents and pH, with Eucalypts generally having higher ash contents and higher acidities (ie lower pH values). Lowest pHs have been recorded for South Australian bluegum, spotted gum, mugga and bloodwood, with highest pHs for white stringybark, jarrah, kurri/mauri, greybox and stoney mallee (Chandler, 1974).

3.2 Nutritional Value

A 100g serve of honey supplies 1320 kilojoules of energy compared to 100g of table sugar (sucrose) which contains 1600 kilojoules of energy. Total carbohydrates vary with 82.1g/100g for honey and 100g/100g for table sugar (sucrose) (English and Lewis, 1992).

3.2.1 Proteins and Amino Acids

The nitrogen content of honey is quite low, on average 0.4%, though it may range to 1% of the total solids. Only 40-65% of the total nitrogen in honey is protein in nature. The remainder of the nitrogen is derived from the free amino acids found only in trace amounts. The most predominant of these are: proline, glutamic acid, alanine, phenylalanine, tyrosine, leucine and isoleucine (D'arcy *et. al.*, 1999)

3.2.2 Minerals, Vitamins and Enzymes

Honey contains small amounts of minerals and vitamins (see Table 4). Many minerals have been identified, including potassium, sodium, calcium, magnesium, iron, copper, chlorine, phosphorous and sulphur. These are of little significance due to their small quantities. All minerals and vitamins in honey are less than 10% of the RDI (Recommended Dietary Intakes) for these micronutrients.

Invertase is the most significant enzyme in honey since invertase added by the honeybee splits the sucrose into constituent sugars and produces other more complex sugars in small percentages during the process. The substrate for invertase is sucrose which is hydrolysed to give glucose and fructose. Diastase (α- and β- amylases) is another predominant enzyme and is frequently used to measure honey quality. It is used as a predictor to determine if honey has undergone any heat treatment. Additionally, glucose oxidase is found in honey and is responsible for the conversion of glucose to gluconolactone, which in turn forms gluconic acid which is the dominant acid in honey (D'arcy *et. al.*, 1999).

Table 4. Minerals and Vitamins in Honey

Vitamins	**Amount in 100g of Honey**
Thiamine	<0.006mg
Riboflavin	<0.06mg
Niacin	<0.36mg
Pyrodoxine (B6)	<0.32mg
Ascorbic Acid (C)	2.2 – 2.4mg
Minerals	
Calcium	4.4 – 9.20mg
Iron	0.06 – 1.50mg
Magnesium	1.2 – 3.5mg
Phosphorus	1.9 – 6.3mg
Potassium	13.2 – 16.8mg
Sodium	0.0 – 7.6mg
Zinc	0.03 – 0.4mg

Source: Stern, 1999

3.2.3 Moisture Content of Honey

The moisture content of honey can vary from as low as 12% to as high as 27% w/w basis with Australian honeys usually 16-18%. The low moisture content together with a high osmotic pressure of honey prevents the growth of bacteria. The water activity of honey is low, 0.5 – 0.6 which is at a level where most bacteria and fungi do not grow.

3.3 Colour

Colour (measured using the industry standard pfund scale) is used as a measure of quality in Australia, with certain colour grades gaining premium prices compared to poorer ones. The colour grades and corresponding pfund values are listed in Table 5.

Colour varies greatly from nearly colourless to yellow, yellow green, gold, amber, dark brown or red brown to almost black.

Table 5. Colour grades of honey and their corresponding pfund values

Colour Grade	Pfund value	Examples
White	Less than 34mm	White Clover
Extra light amber (ELA)	35 – 48mm	Brush Box, Iron Bar,
Light amber (LA)	49 – 65mm	Stringybark, supermarket blend
Pale amber (PA)	66 – 82mm	Blue Gum
Medium amber (MA)	83 – 100mm	Tea Tree, Sugar Cane
Amber	100 – 114mm	Candied
Dark Amber	More than 114mm	Rainforest

Source: D'arcy *et. al*., 1999 and Lower Clarence Skills Centre, 1996

Eucalypt honeys are generally darker than other honeys (Chandler *et. al.*, 1974). Most consumers prefer lighter coloured honey compared to darker coloured honeys (Lower Clarence Skills Centre, 1996).

3.4 Honey Quality

The Australian Honey Industry general specifications for honey of high quality are presented in Table 6.

Table 6. Australian Honey Quality Specification

Moisture	Not more than 20%
Apparent Reducing Sugar	Not less than 65%
Apparent Sucrose	Range from 5 to not more than 15% depending on floral source
Water insoluble solids	Not more than 0.1%
Mineral content (ash)	Not more than 0.6%
Acidity	Not more than 40 milliequivalents acid per 1000 grams
Diastase Activity	Not less than 3
Hydroxymenthylfurfural (HMF)	Not more than 80 mg/kg
Colour	Shall be graded using the Pfund grading standard

Source: Australian Honey Quality Specifications, 2001

The large honey packers of Australia including Capilano (Qld and NSW) and Westcobee (WA) operate a program of quality control keeping safety as a priority. In addition, honey producers who supply the large honey packers are trained in HACCP (food safety), and are regularly audited for food safety and quality.

3.4.1 Granulation and Crystallinity

Glucose monohydrate spontaneously crystallises from honeys that are a supersaturated solution under ordinary storage conditions. Therefore granulation is the result of the crystallisation of glucose caused by a change in the supersaturated state and, in theory, whether a honey will granulate or not will depend on the proportion of glucose to other components of the mixture. Several formulae using the glucose, water and fructose contents of a honey have been suggested for predicting its' susceptibility to crystallisation. None of these formulae are reliable indicators of crystallisation (Chandler *et. al*., 1974).

Rapid crystallisation is expected in honeys from mallee, *yapunyah*, river red gum, while problems of crystallisation should not occur in honeys from coastal *blackbut*t, *grey box, jarrah*, messmate, pink gum, white *stringybark* and yellow box floral sources (Chandler *et. al*., 1974).

4. Honey Types and Geographical Distribution

4.1 The Glycemic Index

The Glycemic Index (GI) is a physiologically based method used to classify carbohydrate foods according to their blood glucose-raising potential. The concept has been widely adopted in diabetes management in Australia, New Zealand, Canada, the United Kingdom and France. The GI compares rise in blood sugar levels after equal carbohydrate portions of foods are ingested and ranks them relative to a standard which is usually glucose or white bread (Brand-Miller *et. al*., 2000).

The Glycemic Index measures the area under the glycemic response curve during a 2-hour period after consumption of a 50g carbohydrate serve from a test food, with values being expressed relative to the effect of either white bread or glucose. As a result, the Glycemic Index is considered a specific property of foods. As shown in Table 12, high Glycemic Index foods are those that have the highest peak circulating glucose in the 2 hour period following food ingestion and the highest area under the curve for the increase in blood glucose above fasting baseline. Conversely, low Glycemic Index foods are those that cause lower peak glucose, demonstrating a smaller area under the curve for the change in blood glucose in the 2-hour period and have a lower risk of causing hypoglycaemia (Roberts, 2000).

Over the last 2 decades more than 600 individual foods have been tested for their Glycemic Index Table 12 summarises some of the foods tested.

Contrary to popular belief, low Glycemic Index foods are not the same as foods based on high complex carbohydrate and fibre, nor are high Glycemic Index foods those based on simple sugars. The foods that produce the highest glycemic responses include many of the starchy foods consumed by people in industrialised countries, including bread, breakfast cereals, and potatoes, whether high or low in fibre. This is because the starch is fully gelatinised and can be rapidly digested and absorbed. The foods with the lowest Glycemic Index values include pasta, relatively unprocessed cereal foods, baked beans, dairy products, and many types of fruit and vegetables. Sugary foods often cause lower levels of glycaemia per gram of carbohydrate than the common starchy staples of western diets. This is because up to half of the weight of carbohydrate is fructose (as is the case with honey), a sugar that has little effect on glycaemia. In fact, the overall Glycemic Index of the diet has been shown to have an inverse correlation with total sugars (refined plus naturally occurring) expressed as a proportion of total carbohydrate (Brand-Miller *et. al*., 2000).

In general, high Glycemic Index foods are those with high carbohydrate content and foods that are rapidly digested. Specific factors that favour increased Glycemic Index include: high-refined carbohydrate content (because fat and protein have minimal effect on blood glucose compared with carbohydrate); high glucose and/or starch content relative to lactose, sucrose and fructose contents (because these sugars yield less glucose, none in the case of fructose); low soluble fibre content because soluble fibre forms a gel in the stomach and reduces the rate of gastric emptying and hence the rate of digestion; and finally, soft, overcooked, highly processed, or over ripened food textures because they are digested more rapidly than foods with greater structural integrity such as firm raw foods, intact grains, and discrete harder pieces of food (Roberts, 2000).

Table 12. The Glycemic Index (GI) of foods

Low Glycemic Index (<55)	GI	Moderate Glycemic Index (56-69)	GI	High Glycemic Index (>70)	GI
Breads		**Breads**		**Breads**	
Pumpernickel	41	Sourdough	57	White bread	70
Heavy mixed grain	30-45	Barley bread	65	Wholemeal bread	72
		Rye bread	65	French bread	95
Breakfast cereals		**Breakfast cereals**		**Breakfast cereals**	
All Bran	42	Cream of wheat	66	Cornflakes	84
Toasted muesli	43	Muesli	66	Rice Bubbles	82
Psyllium-based processed cereal	42				
Dairy foods		**Dairy foods**		Potatoes	80-100
Milk, full fat	27	Ice cream, full fat	61		
Milk, skim	32				
Yoghurt, low fat, fruit	33				
Confectionery		**Confectionery**		**Confectionery**	
Chocolate (Dove)	45	Mars Bar	65	Jelly beans	80
M&Ms	33			Life Savers	70
Snickers Bar	41				
Fruits		**Fruits**		**Fruits**	
Apple	36	Pineapple	52	Watermelon	72
Orange	43	Pawpaw	58		
Peach	28				
Legumes		**Rices**	50-60	**Rices**	70-90
Lentils	28	(high amylose varieties, eg basmati)		(low amylose, white or brown)	
Soybeans	18				
Baked Beans	48			**Honey** (blended not Australian)	87
		Honey (blended Australian)	58		

Reference food is Glucose = 100
Source: Brand-Miller, J and Foster-Powell, K. (1999)

The International Tables of Glycemic Index lists honey as having a Glycemic Index of either 58 or 87 (Powel *et. al.*, 1995). The Glycemic Index of 58 is an Australian blended honey (Brand-Miller, 1995) while the honey with a Glycemic Index of 87 has not documented the source (Jenkins *et. al.*, 1981).

Since the composition of sugars in honey varies depending upon the floral source, it can be assumed that the Glycemic Index of honey will vary depending upon the floral source of the honey. There are important differences between Glycemic Indices of the monosaccharides in honey, notably glucose and fructose levels. Fructose has a Glycemic Index of only about 23. The Glycemic Index of a sugar can be predicted on the basis of the molar ratio of glucose to other monosaccharides in the sugar molecule. This explains why maltose (a disaccharide with two glucose units) has a score close to glucose at 100, whereas sucrose (a disaccharide of glucose and fructose) has a Glycemic Index of only 61. Honey, which contains mixtures of glucose and fructose, may therefore have index values with various ranges (Gurr 1997).

The Australian honey industry has shown a keen interest in finding out the Glycemic Index of individual honeys since the industry was made aware of the Glycemic Index of Australian honey at an annual NSW Apiarists Association conference and follow up paper (Stern, 1999).

4.1.1 Health and the Glycemic Index

Most research relating to the Glycemic Index and health indicates the clinical usefulness in the treatment of diabetes and hyperlipidaemia. Short term studies in lean healthy people, obese individuals, and people with diabetes show consistently higher day long insulin levels with diets based on high Glycemic index foods in comparison with low Glycemic index diets of similar nutrient composition. In people with diabetes, the consumption of high Glycemic index foods results in a far more exaggerated glycemic and insulin response, which may lead to worsening insulin resistance and eventually the need for drug or insulin therapy. Furthermore, higher day long insulin levels promote carbohydrate oxidation at the expense of fatty acid oxidation, thereby encouraging synthesis of very low density lipoprotein cholesterol (VLDL) in the liver and fat storage in adipose tissue. A combination of high Glycemic Index carbohydrate and high fat (of any type) in a meal therefore may be synergistic in promoting weight gain.

Long term studies in animal models show that high Glycemic Index starch increases fasting insulin levels and promotes insulin resistance, in comparison with identical diets based on low Glycemic Index starch.

Recent epidemiological studies indicate that the Glycemic Index of the diet may be the most important dietary factor in preventing type 2 diabetes. Two large scale prospective studies, one in female nurses and one in male health professionals, showed that diets with a high glycemic load (GI x carbohydrate content) increases the risk of developing type 2 diabetes after controlling for known risk factors such as age and body mass index. A similar picture emerged with acute coronary heart disease in the Nurses' study. The underlying mechanism postulated by these authors is the demand for insulin generated by high Glycemic Index foods. Because hyperinsulinaemia is linked with all of the facets of the "metabolic syndrome" (insulin resistance, hyperlipidaemia, hypertension and visceral obesity), the Glycemic Index of foods eventually may be linked with all so-called diseases of affluence.

In healthy people as well as those with type 2 diabetes, high-carbohydrate diets (>50% energy) have been shown to worsen aspects of the blood lipid profile, including the TG, VLDL, HDL and lipoprotein. Individuals with insulin resistance are more susceptible to these adverse effects.

The Glycemic Index has implications for weight control in people with diabetes because slowly digested carbohydrate is associated with higher satiety. The prolonged presence of food in the gut may stimulate chemical and pressure receptors that signal satiety. Low insulinaemic diets have been shown to increase the rate of weight loss on energy restricted diets through the mechanism of lower insulin levels. Thus, low Glycemic Index diets may promote weight control by both enhancing satiety and reducing insulinaemia.

There is also some evidence that the Glycemic Index is relevant to sports nutrition. Low Glycemic Index foods eaten before prolonged strenuous exercise increases endurance time and provides higher concentrations of plasma fuel towards the end of exercise, while high Glycemic Index foods lead to faster replenishment of muscle glycogen after exercise (FAO/WHO, 1997).

5. Methodology

5.1 Honey Collection

Six floral varieties and two commercial blends were chosen for the study after discussions with the RIRDC, R&D Advisory Committee. They were, *Red Gum, Salvation Jane, Ironbark, Yellow Box, Stringybark* and *Yapunyah* and two commercial blends obtained in 2001. Duplicate collection of all honeys at source was ensured. The main Industry contributor was Capilano Honey Ltd from Queensland. The other producers who supplied the honeys were, Wescobee Ltd from WA, Leabrooks Honey Ltd from SA and Department of Agriculture, WA. Red Gum was particularly obtained from SA and WA and the rest were obtained from Capilano Ltd. The purity of the honeys was to a large extent assured by the suppliers. The two commercial blends were obtained from Capilano Honey Ltd and Wescobee Ltd. The composition of the floral varieties or the types that went into the blends was not known. Once the honey samples were received in the laboratory at the Department of Food Science and Technology, The University of New South Wales, they were stored at -18^0C until further analyses.

5.2 Chemical Analyses

The composition of sugars in all the honeys were analysed by a High Pressure Liquid Chromatographic (HPLC) Technique as suggested by Wills *et al*, (1980). Glucose, fructose, sucrose and maltose were analysed. The pH of the samples was tested using a pH meter. Organic acids (oxalic, malic, succinic, lactic, acetic, propionic, citric and butyric acids) were analysed using a standard HPLC technique (AOAC, 2000).

5.3 Glycemic Index Testing

This study was conducted using internationally recognised GI methodology, which has been validated by small experimental studies and large multi-centre research trials. The experimental procedures used in this study were in accordance with international standards for conducting ethical research with humans and were approved by the Medical Ethics Review Committee of Sydney University.

5.3.1 Study Participants (Subjects)

For both parts of the study, a group of 9-10 healthy, non-smoking people aged between 18-45 years was recruited from the staff and student population of the University of Sydney. People volunteering to participate in the study were excluded if they were overweight, were dieting, had a family history of diabetes, were suffering from any illness or food allergy, or were regularly taking prescription medication.

In the first part of the study, a group of seven females and three males was recruited. The average age of the subjects was 27.5 years (range: 19.8 – 44.9 years) and the average body mass index (BMI) score was 22.5 kg/m^2 (range: 20.8 – 25.0 kg/m^2). The BMI score is a measure of a person's weight in relation to their height. BMI values between 19 – 25 kg/m^2 are within the healthy weight range. In the second part of the study, a group of nine females were recruited, five of which had also participated in the first part of the study. Therefore, the two groups of subjects were relatively similar in terms of their age and BMI ranges, and both groups predominantly consisted of females. The average age of the subjects in the second part of the study was 27.9 years (range: 19.7 – 44.9 years) and the average body mass index (BMI) score was 22.3 kg/m^2 (range: 20.2 – 25.0 kg/m^2).

Sample number: With 10 subjects in each group a power of 80% is seen to test the difference of one SD at the 0.05 level. Differences of less than one SD would not be considered a clinically significant difference. This is the usual acceptable size in all GI investigations.

As there is no difference in the glycemic response/glycemic index between male and female, or between lighter and heavier people, each honey was tested in 9 or 10 different individuals. The reference food was tested twice and the average area under the curve for each individual was used.

5.3.2 Test Foods

In both parts of the study, pure glucose sugar (dextrose (D-glucose), Sigma-Aldrich chemical company, Castle Hill, NSW, Australia) dissolved in water was used as the standard reference food and was consumed by each study participant on two separate occasions. Each of the eight types of honey was consumed by each study participant on one occasion only. The reference food and the eight honeys were all served in amounts containing 25 grams of available (digestible) carbohydrate. The weight and sugar content of the test portions of the honeys are listed in Table 13.

Table 13. The weight (g) and sugar content (g) of the test portion of the reference food and honeys

Food	Portion size	Av. Carbohydrate	Fructose	Glucose	Sucrose	Maltose
Reference food	25 g glucose 250 mL water	25.0	0.0	25.0	0.0	0.0
Commercial Blend 1	49.6	25.0	13.6	15.5	0.8	0.7
Commercial Blend 2	35.6	25.0	13.6	10.5	0.3	0.6
Iron Bark	41.7	25.0	14.1	9.8	0.5	0.6
Red Gum	33.9	25.0	11.7	11.2	0.8	1.3
Salvation Jane	40.6	25.0	12.9	11.2	0.4	0.4
Stringy bark	30.4	25.0	15.9	8.5	0.3	0.3
Yapunya	36.9	25.0	15.5	8.8	0.3	0.3

For each study participant, the reference food was prepared the day before required by dissolving 25 grams of pure glucose sugar in a glass of 250 mL of warm water, which was then covered and stored overnight in a fridge. The solution was taken from the fridge shortly before serving to the study participants with a glass of 250 mL of plain water. The test portions of the honeys were weighed into standard glass bowls the day before required and were covered with airtight plastic wrap and stored overnight in a fridge. The next morning, the test portions of the honeys were taken from the fridge

shortly before being served to the study participants with a spoon and a glass of 250 mL of plain water. The study participants were required to consume all of the honey or glucose solution and water served to them. The study participants were instructed to consume all the honey out of the serving bowls.

5.3.3 Experimental Procedures

Using standard GI methodology to determine a food's GI value, a portion of the food containing 25 grams of available carbohydrate is fed to 8-10 healthy people in the morning after they have fasted for 10-12 hours overnight. (The amount of carbohydrate chosen depends on the energy density of the test foods and the size of the test portions. A smaller dose of carbohydrate (25 g) was chosen as subjects could not consume all the honey given to them as the portion size for 50 g carbohydrate content was equivalent to between 30-100g of honey by weight which was too large to be consumed comfortably within 12 minutes). A fasting blood sample is obtained and then the food is consumed, after which additional blood samples are obtained at regular intervals during the next two hours. In this way, it's possible to measure the total increase in blood sugar (glucose) and insulin levels produced by that food. The two-hour blood glucose (glycemic) response for this test food is then compared to the two-hour blood glucose response produced by the same amount of carbohydrate in the form of pure glucose sugar (the reference food: GI value of glucose = 100%). Therefore, GI values for foods are relative measures (ie. they indicate how high blood sugar levels rise after eating a particular food compared to the very high blood sugar response produced by glucose sugar). Insulin index (II) values are calculated in the same way as GI values, substituting the blood glucose response values in the GI equation (see page 8) with the corresponding blood insulin values.

In both parts of this study, the study participants consumed the reference food on two separate occasions, while the honeys were each consumed on one occasion only. The reference food was consumed on both the first and last test sessions, and the honeys were consumed in random order in between.

The day before each test session, the study participants were required to refrain from unusual amounts of eating and exercise, and were required to consume at least 300 grams of carbohydrate for the whole day. In addition, they were required to refrain from consuming alcohol for the whole day and refrain from consuming a legume-based meal during the evening. The night before a test session, the study participants ate a regular evening meal and then fasted for 10-12 hours overnight. During the fasting period, they were allowed to drink only water.

The next morning they reported to the research centre in a fasting condition. The study participants first warmed a hand in a bucket of hot water for two minutes, after which a fasting finger-prick blood sample was obtained from a finger (approximately 0.9-1.2 mL of blood) using an automatic lancet device (Safe-T-Pro®, Boehringer Mannheim Gmbh, Mannheim, Germany). After the fasting blood sample was obtained, study participants were given a fixed portion of a reference food or a honey, which they consumed with 250 mL of plain water at a comfortable pace within 12 minutes. The study participants were required to consume all of the honey or reference food and water served to them. The participants were then required to remain seated at the research centre and refrain from eating and drinking during the next two hours. Additional blood samples were taken 15, 30, 45, 60, 90 and 120 minutes after eating had commenced. Therefore, a total of seven blood samples were collected from each subject during each two-hour test session.

5.3.4 Measurement of Blood Glucose Responses

For each study participant, the concentration of glucose in the plasma component in each of their seven blood samples was analysed in duplicate using the glucose hexokinase enzymatic method (Roche Diagnostic Systems, Sydney, Australia) and an automatic centrifugal spectrophotometric analyser (Roche/Hitachi 912®, Boehringer Mannheim Gmbh, Mannheim, Germany) using internal

controls. The glucose concentrations in the seven blood samples were then used to graph a two-hour blood glucose response curve, which represents the total two-hour glycemic response to that food (ie. the total rise in blood sugar induced by the digested food). The area under this two-hour blood plasma glucose response curve (AUC) was calculated using the trapezoidal rule (1), in order to obtain a single number, which indicates the magnitude of the total blood glucose response during the two-hour period. A glycemic index (GI) value for the test food was then calculated by dividing the two-hour blood glucose AUC value for this test food by the subject's average two-hour blood glucose AUC value for the reference food and multiplying by 100 to obtain a percentage score.

GI value for test food (%) = Blood glucose AUC value for the test food x 100

AUC value for the same carbohydrate portion of the reference food

Due to differences in body weight and metabolism, blood glucose responses to the same food can vary between different people. The use of the reference food to calculate GI values reduces the variation between the subjects' blood glucose results to the same food arising from these natural differences. Therefore, the GI value for the same food varies less between the subjects than their glucose AUC values for this food. In this study, the final GI value for each honey is the average of the 9-10 subjects' GI values for that honey.

5.3.5 Measurement of Blood Insulin Responses

For each study participant, the concentration of insulin in the plasma component in each of their seven blood samples collected during each test session was analysed using a solid-phase antibody-coated tube radioimmunoassay kit (Diagnostic Products Corporation, Los Angeles, CA, USA) with internal controls. The plasma insulin concentrations in the seven blood samples were then used to graph a two-hour blood insulin response curve, which represents the study participant's total two-hour insulinaemic response to that food. The area under this two-hour blood plasma insulin response curve (AUC) was calculated and an insulin index (II) value for the honey was then calculated using the GI formula shown above, substituting the insulin AUC results for the glucose AUC results.

6. Results and discussion

6.1 Chemical analyses

6.1.1 Carbohydrate composition

The mean sugar content of the six floral varieties and two commercial blends are given in Table 14.

Table 14 Mean available sugar content (g/100g) of honeys

Honey varieties	Glucose	Fructose	Sucrose	Maltose	Total
Commercial Blend 1(NSW)	20.3 ± 0.3	27.5 ± 1.0	1.1 ± 0.2	1.5 ± 0.2	50.4 ± 0.4
Commercial Blend 2 (WA)	29.6 ± 0.4	38.1 ± 1.1	0.9 ± 0.1	1.6 ± 0.3	70.2 ± 0.5
Iron Bark	23.6 ± 0.5	33.8 ± 0.8	1.1 ± 0.2	1.4 ± 0.2	59.9 ± 0.5
Red gum	32.9 ± 0.9	34.6 ± 0.7	2.5 ± 0.4	3.7 ± 0.4	73.7 ± 0.6
Salvation Jane	27.7 ± 0.8	31.9 ± 1.0	0.9 ± 0.1	1.1 ± 0.1	61.6 ± 0.5
Stringybark	27.9 ± 1.0	52.4 ± 1.3	1.0 ± 0.1	1.0 ± 0.1	78.3 ± 0.6
Yapunya	23.9 ± 0.5	42.1 ± 1.9	0.8 ± 0.1	0.9 ± 0.2	67.7 ± 0.6
Yellow Box	26.8 ± 0.7	45.5 ± 2.1	0.9 ± 0.1	1.1 ± 0.2	74.3 ±0.8

The above values are means of duplicate determinations

The glucose content ranged from 20.3- 32.9 g/100g with the commercial blend (1) (NSW) having the least and *Red gum* having the highest. Fructose levels varied from 27.5-52.4 g/100g with the commercial blend (1) having the least and S*tringybark* was having the highest. Sucrose content was low in all samples (0.9-1.1g/100g) excepting in R*ed gum*. The maltose levels ranged from 0.9-3.7 g/100g with *Yapunyah* having the least and *Red gum* was having the highest. The total sugar content varied between 50.4 and 78.3 g/100g with the commercial blend (1) having the least and Stringybark was having the highest. Sugar contents are in line with literature values.

6.1.2 Organic acids

The organic acid contents measured using a HPLC technique revealed Malic and succinic acids to be the predominant ones. Oxalic, tartaric, malic, succinic, lactic, acetic, propionic, citric and butyric acids were identified. Table 15 indicates the contents of the acids.

Table 15 Mean organic acids (mg/100g) content of honeys

Honey	Oxalic	Tartar	Malic	Succin	Lactic	Acetic	Propio	Citric	Butyri
Com.1	0	0	0.97	0.12	0	0.04	0	0.03	0
Com.2	0.03	0	1.07	0.13	0	0.04	0.04	0	0
Red Gum	0.13	0.1	0.02	1.1	0.02	0.02	0.02	0	0
S.Jane	0	0	0.92	0.12	0	0	0	0.01	0
Iron Bark	0	0.13	1.41	0.13	0	0	0	0.05	0
Yellow Box	0.01	0.06	1.33	0.07	0	0	0	0.01	0
Stringy Bark	0.11	0.1	1.35	0.26	0	0	0	0.03	0
Yapunyah	0	0.01	1.4	0.22	0	0	0	0.04	0.6

The above values are means of duplicate analyses.

6.1.3 pH of the honeys

The pH of the honeys ranged from 5.2-6.1. Some honeys ranged from 5.2-5.8 (*Salvation Jane*, Commercial blend (1) and *Yellow Box*. The others ranged from 6.0- 6.4 (*Yapunyah*, *Stringybark*, Commercial blend (2), *Red Gum* and *Iron Bark*).

6.1.4 Osmolality of honeys

Using an osmometer, the honeys were tested for their osmolality in replicates. They ranged from 4804- 4884 for *Salvation Jane*, *Iron Bark*, Commercial blend (2), and *Red gum*. The rest had a range of 5676-5708 for *Yellow Box*, *Stringybark* and Commercial blend (1).

6.2 GI Testing

The study was divided into two parts with 3 honeys tested in the first lot and the rest in the second lot. The three honeys that were tested first were Yellow Box, Iron Bark and Salvation Jane. The average two-hour blood glucose response curves for the reference food and the three honeys tested in the first part of the study are shown in Figure 1. The reference food produced the highest overall glycaemic response curve producing a large rise and fall in the level of blood glucose. The peak blood glucose level and pattern of the two-hour glycaemic response curves varied among the honeys. On average, the Salvation Jane honey produced the largest response curve and the Yellow Box honey produced the lowest response curve.

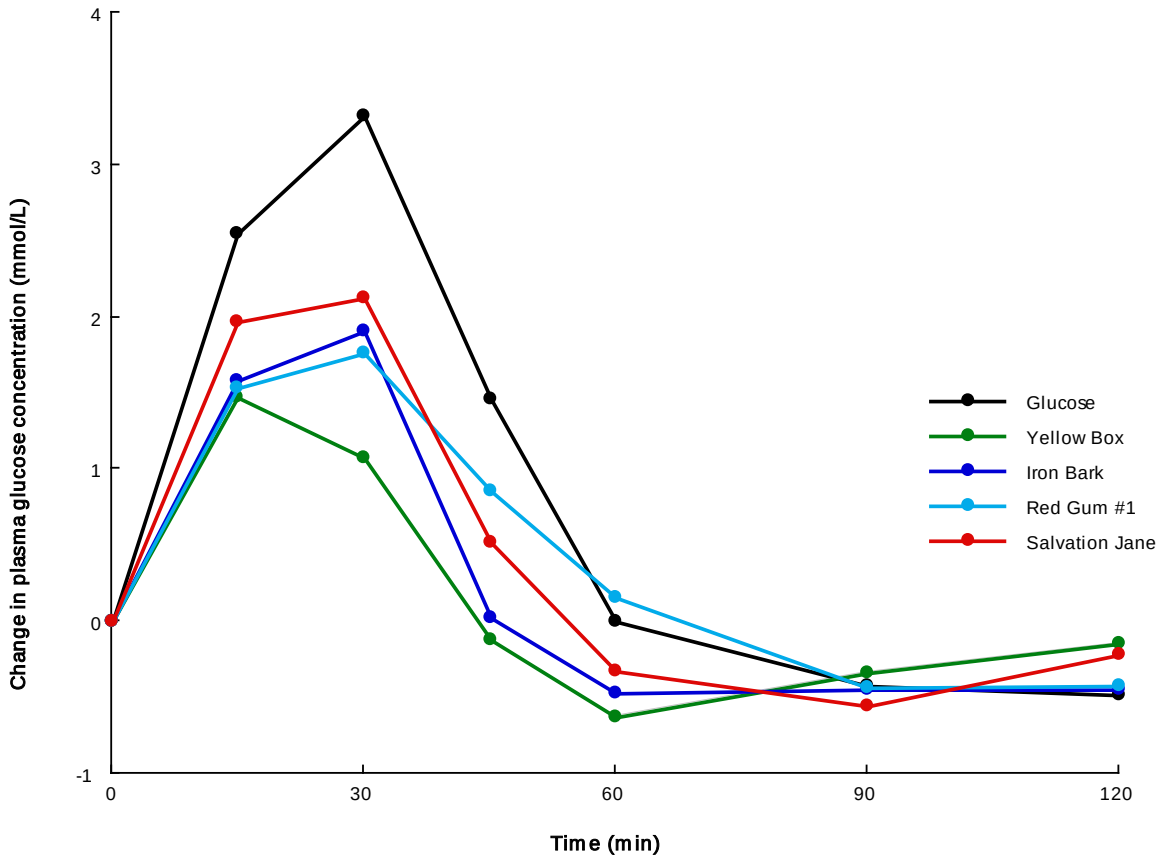

Figure 1. The average plasma glucose response curves for the reference food and the four honeys tested in the first part of the study, depicted as the change in glucose concentration from the fasting baseline level.

The average blood insulin response curves for the three honeys tested in part 1

The average two-hour blood glucose response curves for the reference food and the three honeys tested in the first part of the study are shown in Figure 3. The patterns of the blood insulin response curves were not exactly the same as their corresponding glycaemic response curves. The reference food produced the highest overall insulin response curve and the insulin response curves for the honeys varied to a greater extent than their glycaemic response curves. The reference food produced the highest insulin response curve followed by Salvation Jane honey, Iron Bark honey, and, lastly, the Yellow Box honey.

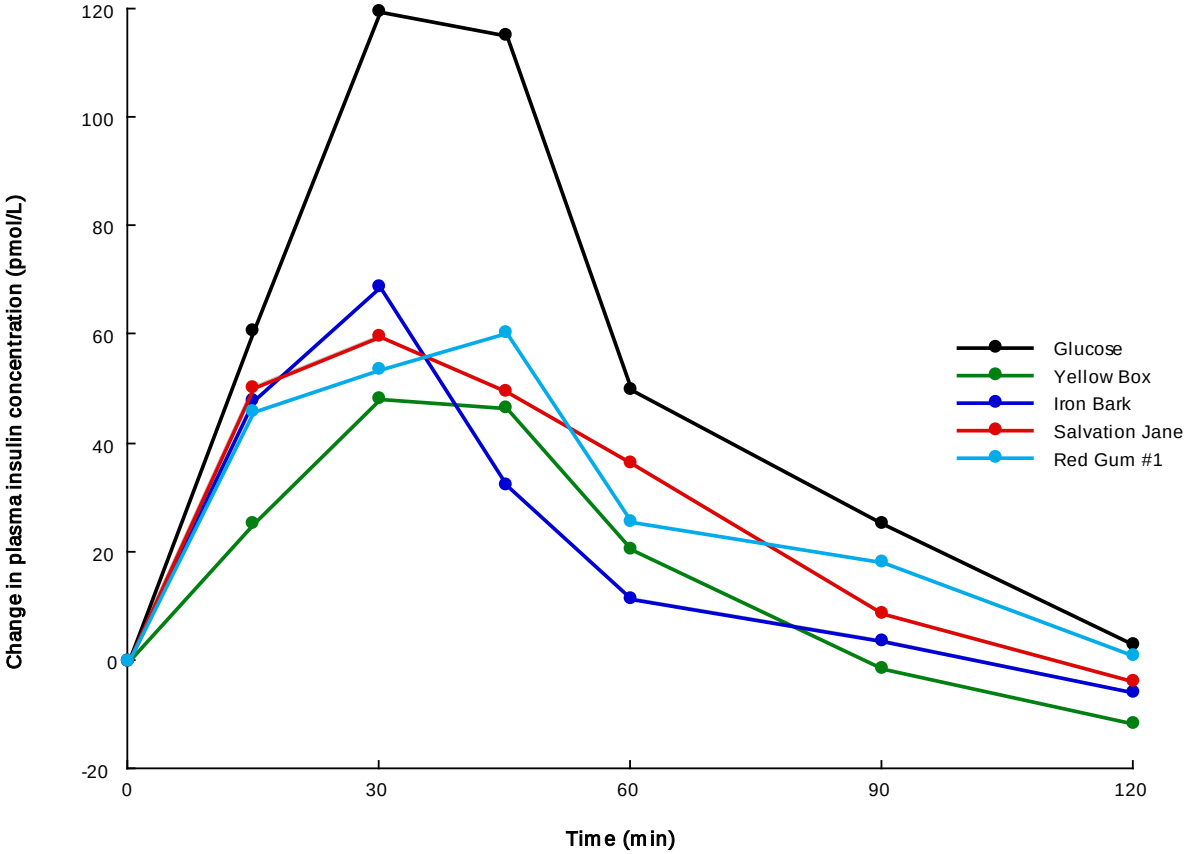

Figure 2. The average plasma insulin response curves for the reference food and the four honeys tested in the first part of the study, depicted as the change in blood insulin concentration from the fasting baseline level

The average blood glucose response curves for the five honeys tested in part 2

The average two-hour blood glucose response curves for the reference food and the five honeys tested in the second part of the study are shown in Figure 3. The reference food produced the highest overall glycaemic response curve and the response curves for the five honeys varied markedly with the Commercial Blend #1 honey producing the largest overall response curve and the Stringybark honey producing the smallest response curve.

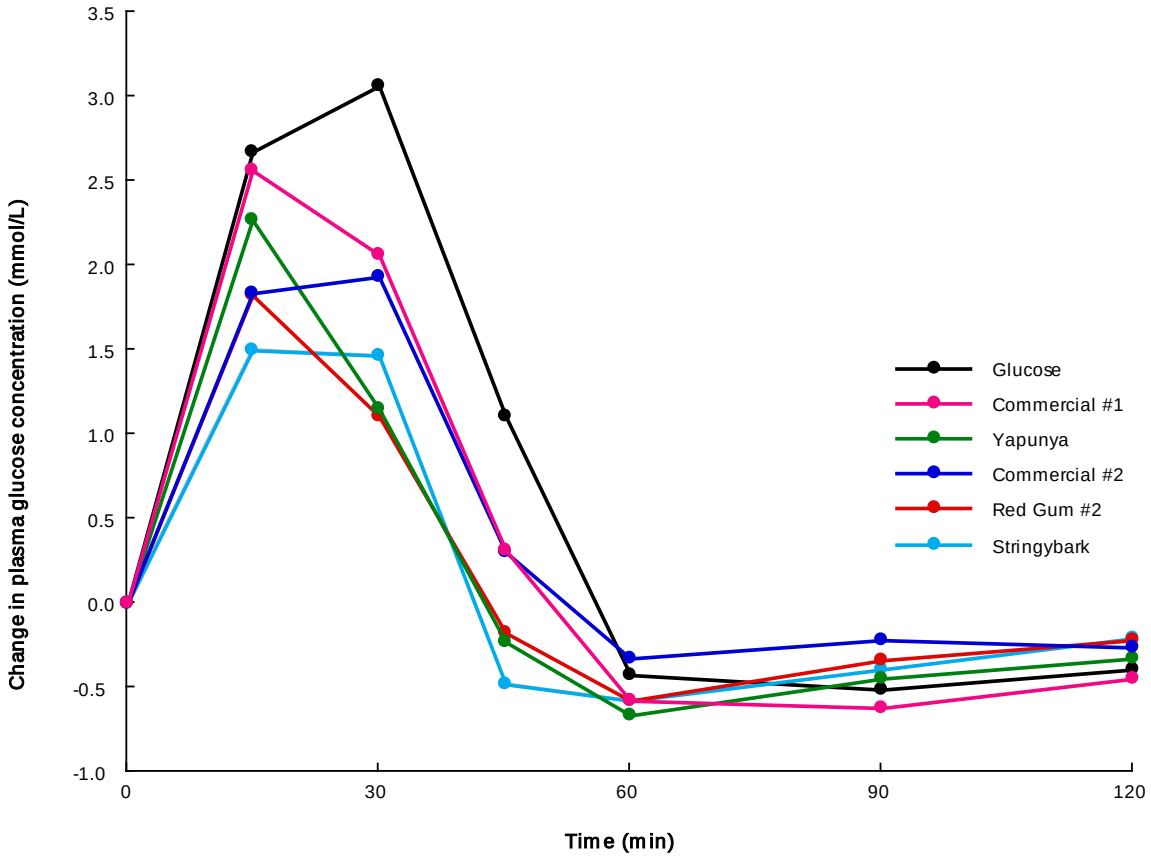

Figure 3. The average plasma glucose response curves for the reference food and the five honeys tested in the second part of the study, depicted as the change in glucose concentration from the fasting baseline level.

The average blood insulin response curves for the five honeys tested in part 2

The average two-hour blood glucose response curves for the reference food and the five honeys tested in the second part of the study are shown in Figure 4. The reference food produced the highest insulin response curve and the five honeys produced a range of insulin responses, varying in the peak insulin concentration, and the rate of rise and fall in blood insulin levels. Among the honeys, the Commercial blend # 1 honey produced the highest integrated two-hour insulin response and the Stringybark honey produced the lowest.

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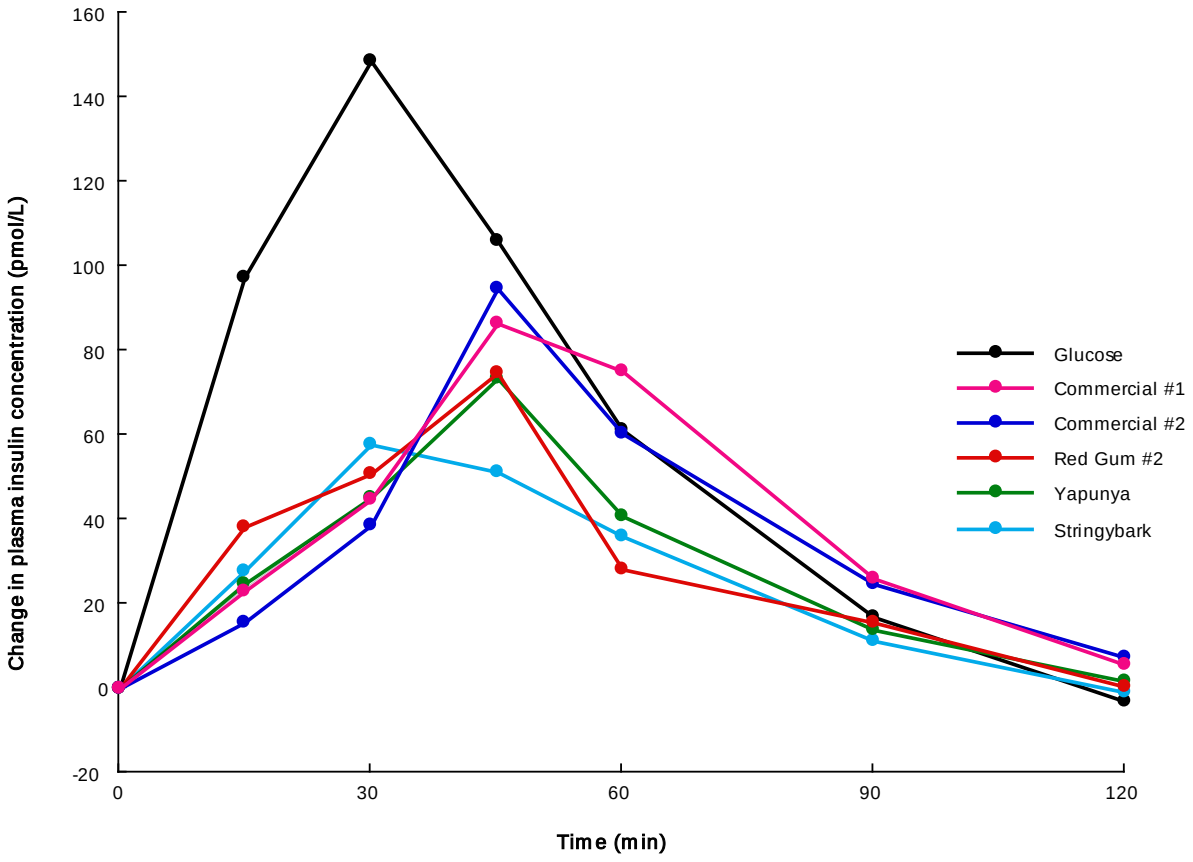

Figure 4. The average plasma insulin curves for the reference food and the five honeys tested in the first part of the study, depicted as the change in the blood insulin concentration from the fasting baseline level

Glycaemic and Insulin Index values

The GI and II values for each of the honeys tested varied among the 10 subjects who participated in the study. This variation in GI and II values for the same food between people is normal and is due to a number of factors, such as the different rates at which the subjects ingested the foods, and genetic factors affecting the metabolism of carbohydrate. The average (mean) GI and II values (mean ± standard error of the mean) for the nine honeys are listed in Table 16 and illustrated in Figure 5.

Table 16. The mean ± SEM GI and II values for the nine honeys, using glucose sugar as the reference food (ie GI and II value for glucose = 100).

Test Food	**GI value (%)**	**II value (%)**
Yellow Box honey	40 ± 5	35 ± 4
Stringybark honey	47 ± 3	44 ± 4
Red Gum honey	51 ± 3	46 ± 3
Iron Bark honey	42 ± 4	48 ± 3
Yapunya honey	52 ± 5	49 ± 3
Commercial blend # 2 honey	62 ± 4	62 ± 3
Salvation Jane honey	52 ± 3	64 ± 5
Commercial blend # 1 honey	67 ± 6	72 ± 6
Reference food (glucose)	100 ± 0	100 ± 0

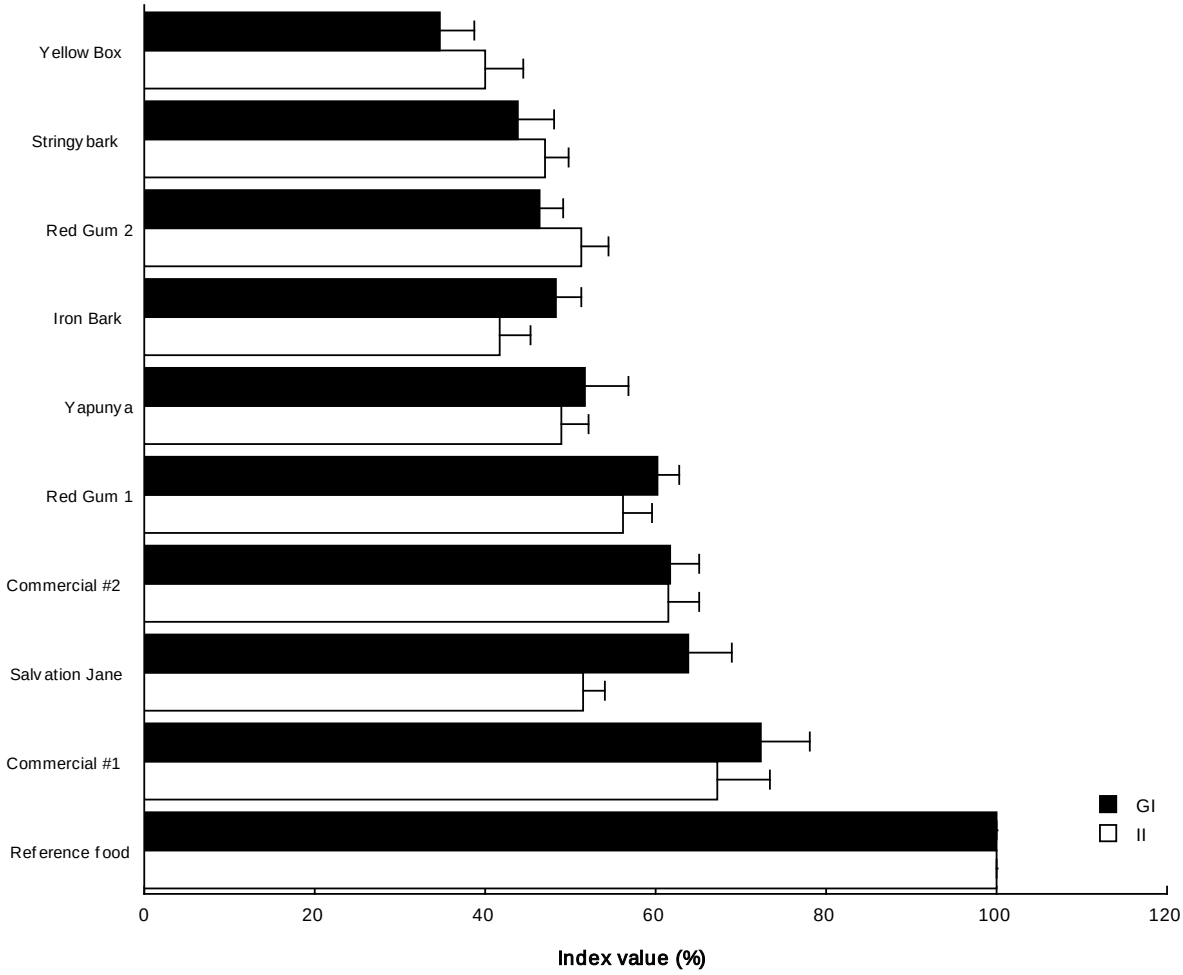

Figure 5. The average GI and II values (mean ± SEM) for the nine honeys and reference food.

Significant differences among the honeys' average GI and II values

Standard statistical tests (Analysis of Variance and the Fisher PLSD test for multiple comparisons) were used to determine whether the average GI and II values for the honeys were significantly lower than the GI and II value of the reference food and whether significant differences existed among the honeys'. The smaller the p value, the more significant the difference, with $p<0.001$ (99.9%) being the most significant difference followed by $p<0.01$ and lastly $p<0.05$.

Significant differences among GI values

Due to the different number of subjects in each part of the study, the results from the two parts of the study were analysed separately.

For the first part of the study, the GI value for the reference food (glucose sugar) was significantly greater than the average GI values for all four honeys tested, with the difference being highly significant ($p<0.001$). The average GI value of the Salvation Jane honey was significantly greater than the average GI values of the Yellow Box honey ($p<0.001$) and the Iron Bark honey ($p<0.01$). The average GI value of the Iron Bark honey was significantly greater than that of the Yellow Box honey ($p<0.01$).

For the second part of the study, the GI value for the reference food (glucose sugar) was significantly greater than the average GI values for all five honeys tested, with the difference being highly significant ($p<0.001$). The average GI value of the Commercial blend honey # 1 was significantly greater than the average GI values of the Stringybark, Yapunya, Red Gum ($p<0.001$), and Commercial blend # 2 ($p<0.05$) honeys. The average GI value of the Commercial blend honey # 2 was significantly greater than the average GI values of the Stringybark ($p<0.001$), Red Gum ($p<0.01$), and Yapunya ($p<0.05$) honeys.

Significant differences among II values

Due to the different number of subjects in each part of the study, the results from the two parts of the study were analysed separately.

For the first part of the study, the II value for the reference food (glucose sugar) was significantly greater than the average II values for all four honeys tested, with the difference being highly significant ($p<0.001$). The average II value of the Salvation Jane honey was significantly greater than the average II values of the Iron Bark and Yellow Box honeys ($p<0.05$).

For the second part of the study, the II value for the reference food (glucose sugar) was significantly greater than the average II values for all five honeys tested, with the difference being highly significant ($p<0.001$). The average II value of the Commercial blend honey # 1 was significantly greater than the average II values of the Stringybark, Yapunya, and Red Gum ($p<0.001$) honeys. The

average II value of the Commercial blend honey # 2 was significantly greater than the average II values of the Stringybark, Yapunya ($p<0.01$) and Red Gum ($p<0.05$) honeys.

Relationship between the honeys' average GI and II values

Linear correlation analysis showed that the average GI and II values for the honeys were significantly associated ($r = 0.875$, $n = 9$, $p<0.001$) (Figure 6). Plasma glucose and insulin responses typically show a highly significant association for low-fat, high-carbohydrate foods. The insulin responses were not exaggerated in relation to their corresponding glycaemic responses. Therefore, the nine honeys tested do not appear to contain any insulinogenic components, other than sugar.

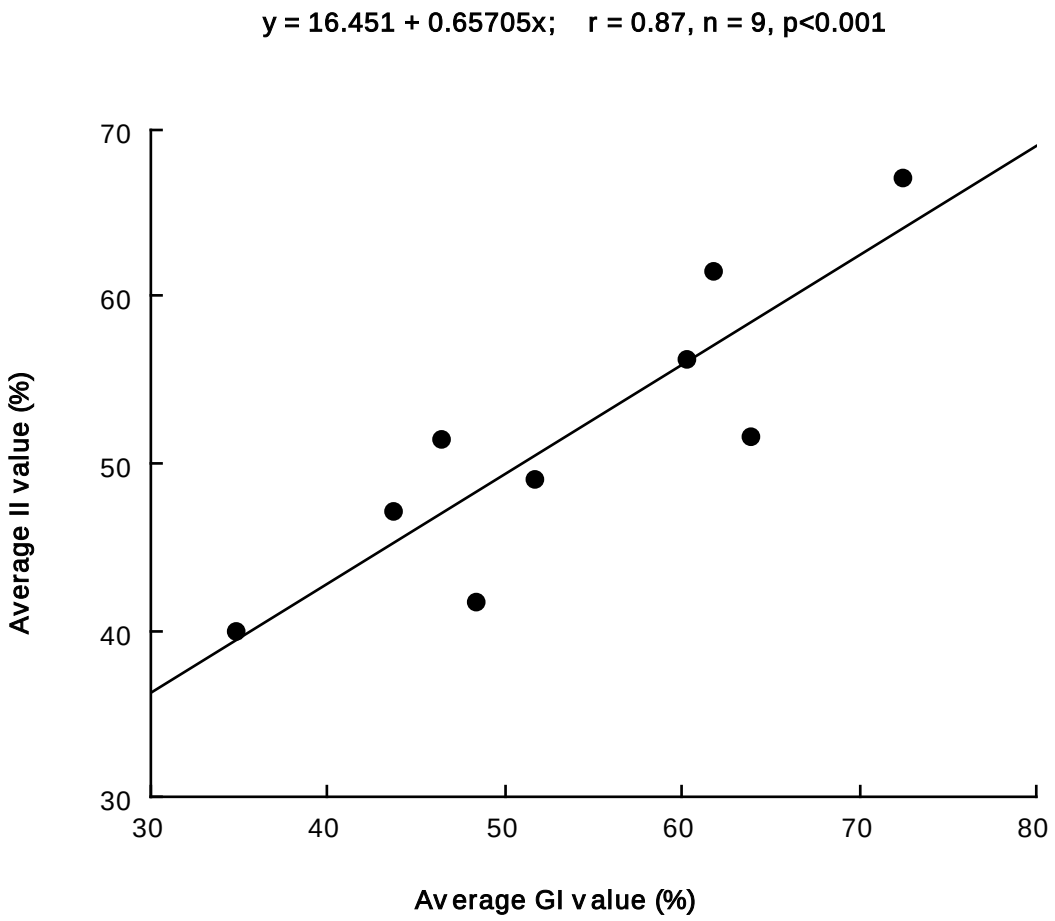

Figure 6 The relationship between the nine honeys' average GI and II values

Relationship between the honeys' sugar contents and GI and II values

Linear correlation analysis was used to examine the association the honeys' content of single sugars (fructose, glucose, sucrose and maltose (g/100 g)) and the average GI and II values.

Only the honeys' fructose content was significantly associated with the average GI values ($r = - 0.76$, $n = 9$, $p<0.05$) and average II values ($r = - 0.67$, $n = 9$, $p<0.05$). The other individual sugars were not significantly associated with either the GI or II values.

Regression analyses of GI, total sugars, fructose, organic acids, pH and osmolality

A regression analysis between GI, total sugars, fructose and organic acid contents and pH and Osmolality revealed an association between the variables with an r^2 value of 0.61. This meant that the independent variables such as the sugars, fructose and organic acid contents and the pH and osmolality values influenced the variable GI to the extent of 61% but was not significant.

7. Implications

Using glucose as the reference food (GI = 100), foods with a GI value of 55 or less are currently considered to be low-GI foods. Foods with a GI value between 56-69 have an intermediate or moderate GI rating, and foods with a GI value of 70 or more are high-GI foods. Therefore, the *Yellow Box, Stringybark, Red Gum, Iron Bark* and *Yapunya* honeys are low GI foods and are more suitable for consumption, in controlled amounts, by people with diabetes and other health problems associated with poor blood glucose control (eg. pancreatic disease, polycystic ovarian syndrome, Diabetes), in line with their dietary requirements. Commercial blend # 2 (SA) and *Salvation Jane* honeys are moderate GI foods and the Commercial blend # 1 (NSW) honey is a high-GI food. There is no cut-off value for insulin index. At present, we do not know the clinical significance of a food which has a low GI but high insulin index.

The results of this study show that different honeys can have significantly different effects on blood glucose and insulin levels, due to differences in their sugar content and physical form, and should not all be classified as one type of food for people with diabetes.

8. Recommendations

- The low GI honeys such as *Yellow Box, Stringybark, Red Gum, Iron Bark, Yapunyah* and the moderate GI honeys such as Commercial blend #2 and *Salvation Jane* can be marketed by stating in their promotional materials that the GI values of the honeys were measured using valid scientific methodology through this project.
- The values should be published in relevant GI publications particularly in the future editions of Brand-Miller's books about the GI (The GI Factor series) which will be appropriately referenced.
- Finally there may be more floral varieties of honey that need to be tested. One question that needs further research – is any pure floral honey low GI? For example, is any Yellow Box honey low GI?

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