Glycemic Index and Glycemic Load

Beneficial Roles of Citrus

Executive Summary

Sandy Barros and Filomena Valim

In some parts of the world glycemic index (GI) is now widely recognized as a reliable, physiologically based classification of foods according to their postprandial (after meal) glycemic effect (a measure of the change in blood glucose following ingestion of carbohydrate containing foods).

Due to the absence of specific information on the glycemic index and glycemic load of Florida orange juices, the Department of Citrus contracted with Glycemic Solutions, a professional clinical research organization, to determine the GI and GL of three commercially available 100% Florida orange juices. The juices evaluated were a premium not from concentrate juice, a premium not from concentrate with high pulp juice and a from concentrate juice. The results of these evaluations are shown in Table 1.

Table 1 - Glycemic Index/Glycemic Load Results

OJ	GI	GL	CHO
NFC – 4 oz.	33	4.3	---
NFC 8 oz.	48	12.5	26.1 g
NFC-high pulp – 4 oz.	34	4.5	---
NFC-high pulp – 8 oz.	47	12.5	26.7 g
From Concentrate – 4 oz.	27	3.6	---
From Concentrate – 8 oz.	48	12.9	26.9 g

Brand-Miller and associates set the following values for low, medium and high GI foods, using glucose as the reference food: Low GI = 55 or less, Medium GI = 56-69 and, High GI = 70 or more. Brand-Miller also set the following range of values for low, medium and high GL values for individual foods as follows: Low GL = 10 or less, Medium GL = 11-19 and High GL = 20 or more. A typical diet has approximately 100 GL units per day (range 60-180).

Based on the results shown in Table 1, there is no scientific based evidence as reported below to exclude citrus juice as part of any healthy diet including most popular low-carbohydrate diets.

Carbohydrates have been classified as simple or complex (sugar, starch and fiber) based on their degree of polymerization. However, their effects on health may be better described on the basis of their physiological effects, which depend both on the type of constituent sugars and the physical form of the carbohydrate. The level of postprandial glycemia, however, is dictated both by the quality and the quantity of carbohydrate. To consider both factors simultaneously, the concept of glycemic load (GL) was introduced. GL is defined as the product of the carbohydrate content per serving of food and its GI.

The initial intent of glycemic index values was to prescribe a varied diet of low glycemic index foods for diabetics. Though endorsed by many official health agencies around the world, as a method to classify carbohydrate rich foods, the principles underlying GI and GL have not been recognized by any governmental or professional entity in the United States. In recent years the uses of GI and GL have been expanded to include being perceived as a key player for the prevention of diseases and obesity.

The understanding of the meanings of glycemic index, glycemic load, and glycemic load of a meal (the sum of the GL contribution of individual foods making up a meal) can be confusing to the average consumer. To make matters worse, the glycemic index of a food can be determined by various methods (time over which standard blood glucose is measured, how blood samples are withdrawn, etc), using various reference foods (glucose or white bread) and the health status of the subjects. It would be beneficial if a single standardized methodology were agreed upon by all organizations endorsing the use of glycemic index.

Recent economic data has shown that the advent and popularity of the low carbohydrate diets such as the South Beach Diet have had a negative effect on citrus juices sales. These diets suggest the use of the GI as a guideline for meal planning, focusing on the use of low GI foods. The South Beach Diet specifically excludes all fruit juices as part of its diet plan.
Orange juice has been categorized as a low GI food whose GL value is on the low end of the medium range category. Among the foods providing carbohydrates, orange juice is a nutrient dense, fat-free food that provides a variety of nutrients for maintenance of good health.

Therefore, there is no scientific based evidence to exclude citrus juice as part of any healthy diet including most popular low-carbohydrate diets, however, there is plenty of evidence to support that citrus and citrus juices are a healthy addition to any diet.

For a more detailed and referenced review of this topic, please continue reading below.

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Literature Review

Sandy Barros and Filomena Valim

1- INTRODUCTION

In some parts of the world glycemic index (GI) is now widely recognized as a reliable, physiological based classification of foods according to their postprandial (after meal) glycemic effect (a measure of the change in blood glucose following ingestion of carbohydrate containing foods). The GI was introduced in the early 1980's by Jenkins and co-workers and later proposed by Jenkins et al (1985) as a possible tool for the management of type 1 diabetes[a] and disorders of lipoprotein metabolism (dyslipidemia).

In 1997, a joint committee of the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) reviewed the available research evidence regarding the importance of carbohydrates in human nutrition and health. That committee endorsed the use of GI method for classifying carbohydrate rich foods, and recommended that the GI values of foods be used in conjunction with information about food composition to guide food choices (FAO/WHO, 1997).

Though endorsed by many official health agencies around the world, the principles underlying GI have not been recognized by any governmental or professional entity in the United States. The American Diabetes Association, in a recent review, states in its position that: "Although the use of low GI foods may reduce postprandial hyperglycemia, there is not sufficient evidence of long-term benefit to recommend use of low GI diet as a primary strategy in food/meal planning" (Franz et al, 2002).

Laboratories around the world are currently conducting commercial testing of foods for GI for the food industry.

[a] type 1 diabetes or insulin dependent diabetes mellitus, IDDM, is the result of the absolute deficiency of insulin as a consequence of β-cell loss or damage – while in type 2 diabetes or non-insulin dependent diabetes mellitus, NIDDM, insulin is secreted, sometimes in greater than normal amounts, but is a relative deficiency of insulin due to increased tissue resistance to insulin action. Usually begins in middle aged or older people, however it is seen in a few young person. (Stubbs, 1983).

GI addresses the quality of carbohydrates but not the effect of the quantity of carbohydrates in a food portion on glycemia. The glucose and insulin responses depend on both the quantity and quality of the carbohydrates. Salmeron et al (1997) introduced the term glycemic load (GL) to improve the reliability of predicting the glycemic response of a given diet. The GL of a food is its amount of carbohydrate in a serving multiplied by its glycemic index.

One concern with GL is that it is a mathematical concept, and has not been physiologically validated as a reliable measure of glycemic response (Ludwig, 2003).

Florida Department of Citrus' economic research department has shown that the advent and popularity of the Atkins' and South Beach diets have had a negative effect on citrus juices sales. Both of these diets are low carbohydrate diets and suggest the use of GI as a guideline for meal planning, focusing on the use of low GI foods. The South Beach Diet specifically excludes citrus juices as part of its diet plan (Agatston, 2003).

This report on GI and GL is aimed to address the issue of citrus juices in the context of its suitability as part of any healthy diet. Citrus juices are one of the most readily available, high nutrient dense, no-fat foods and are listed as a low category GI food (Foster-Powell et al, 2002; Brand-Miller et al, 1996).

2- REPORT

2.1– Definitions:

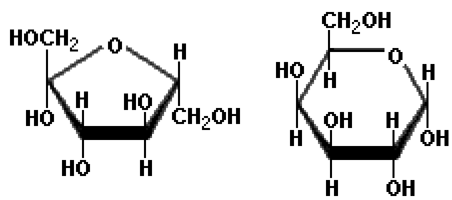
Glycemic Index

Glycemic index (GI) is defined as the incremental area under the blood glucose response curve of a 50g carbohydrate portion of a test food expressed as a percent of response to the same amount of carbohydrate from a reference food (white bread or glucose) taken by the same subject over a specified period of time (Jenkins et al, 1981). It compares equal quantities of carbohydrates and provides a measure of carbohydrate quality and not quantity (Foster-Powell et al, 2002).

Carbohydrates

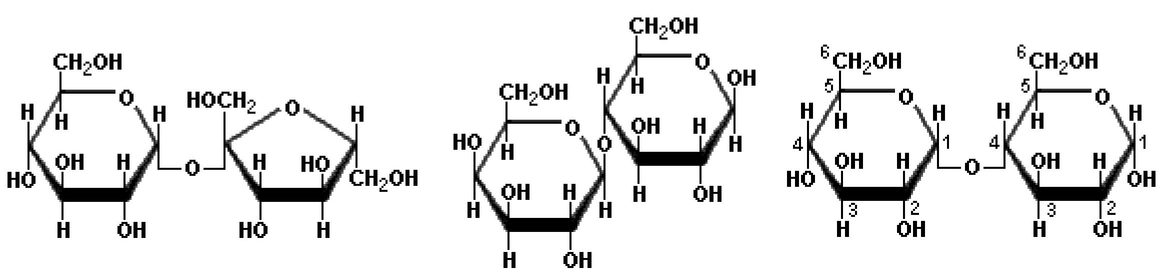
Carbohydrates are an important part of a healthy diet because they provide fuel for the body. They are found in foods in a variety of forms. The most common and abundant ones are sugars, fibers, and starches.

Carbohydrates have been classified as *simple* or *complex* based on their degree of polymerization. *Simple* carbohydrates included monosaccharides, such as fructose and glucose, and disaccharides such as sucrose, lactose and maltose. Figures 1 and 2 show the chemical structure of those mono and disaccharides.



Fructose Glucose

Figure 1- Monosaccharides



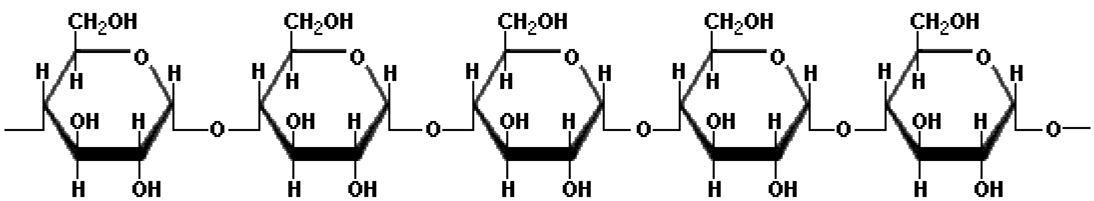
Sucrose Lactose Maltose

Figure 2 – Disaccharides

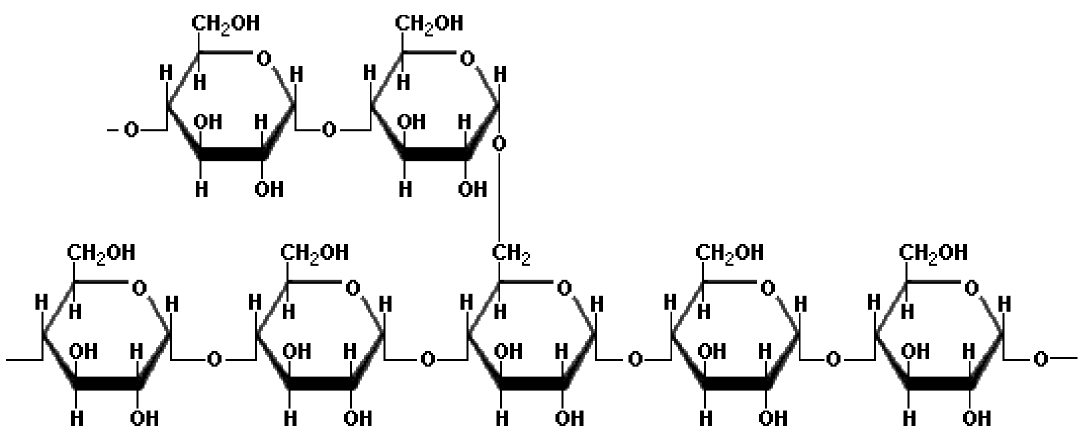
Complex carbohydrates include everything made of three or more linked monosaccharides, with various degrees of cross-linking, like starches and fibers.

Starch is composed of a mixture of two substances: amylase, an essentially linear polysaccharide, and amylopectin, a highly branched polysaccharide (Figure 3).

Many polysaccharides, unlike sugars, are insoluble in water. Dietary fiber includes polysaccharides and oligosaccharides that are resistant to digestion and absorption in the human small intestine but which are completely or partially fermented by microorganisms in the large intestine.



Amylose



Amylopectin

Figure 3 – Structure of starch: formed from amylose and amylopectin

A person’s digestive system handles all carbohydrates in the same manner. It basically breaks down the carbohydrates into monosaccharides, which can then be absorbed into the blood stream. The digestive system converts the carbohydrates to glucose, because our cells are designed to use glucose as a universal energy source.

Fiber is an exception. The fiber molecule is structured in such a manner that humans cannot break it down into monosaccharides and thus it passes through the body mostly undigested. They can be categorized by their source of origin or by how easily they dissolve in water. *Soluble fibers* with few or no ramifications can be partially dissolved in water, whereas, *insoluble fibers* are highly ramified do not dissolve in water.

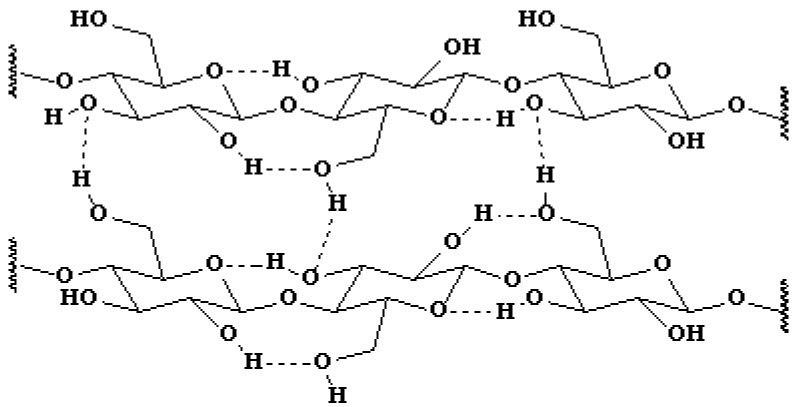


Figure 4 – Fiber structure

Table 1 lists some food sources of fiber and how they are categorized.

Table 1 - Food Sources of Fiber

FOOD	SERVING SIZE	TOTAL FIBER (GRAMS)	SOLUBLE FIBER (GRAMS)	INSOLUBLE FIBER (GRAMS
English Muffin	1	2.0	.5	1.5
Spaghetti, cooked	1 cup	2.0	.5	1.5
Whole-wheat bread	1 slice	2.5	.5	2.0
White rice, cooked	1/2 cup	.5	0	.5
Bran flake cereal	1/4 cup	5.5	.5	5.0
Corn flake cereal	1 cup	1.0	0	1.0
Oatmeal, cooked	1/4 cup	3.0	1.0	2.0
Apple, with skin	1 medium	3.0	.5	2.5
Orange	1 medium	2.0	.5	1.5
Pear, with skin	1 medium	4.5	.5	4.0
Strawberries	1 medium	1.0	0	1.0
Broccoli	1/2 cup	2.0	0	2.0
Corn	1/2 cup	1.5	0	1.5
Potato, baked with skin	1 medium	4.0	1.0	3.0
Spinach	1/2 cup	2.0	.5	1.5
Kidney beans	1/2 cup	4.5	1.0	3.5
Popcorn	1 cup	1.0	0	1.0
Peanut butter, chunky	2 tbsp	1.5	0	1.5

Sources: Carol Meerschaert, RD, LDN. Fiber Talk. Today’s Dietician 3:23-24, 2001American Institute for Cancer Research. How to Lower Your Cancer Risk: The Facts About Fiber. Washington D.C. 2001.Linda Boeckner. Nebraska Cooperative Extension. Neb Facts. University of Nebraska-Lincoln. NF 92-62.www.GNC.com/healthnotes/Index/high fiber.htmwww.nutrifitonline.com

As shown in table 1 approximately 75% of the total fiber in an orange is insoluble fiber.

2.2 – Glycemic index and its implications:

Single and complex carbohydrates differ in terms of their postprandial metabolic and hormonal responses due to factors such as food form, dietary fiber and the nature of carbohydrate. This means that carbohydrates may be better described on the basis of their physiological effects: their ability to raise blood glucose.

In order to quantify the variation in rates of absorption of carbohydrates into the blood stream, and their postprandial glucose responses, Jenkins et al (1981) developed the GI and calculated the relative glycemic effects of carbohydrate exchanges for 51 foods.

Foster-Powell & Miller (1995) published the first international table of GI values. In 2002, the table was revised and the International Table of Glycemic Index and Glycemic Load Values were published. The table was compiled from both published and unpublished data from verified sources and contains nearly 1300 entries representing over 750 different foods tested using standard methods (Foster-Powell et al, 2002).

Glycemic index values for meat, poultry, fish, avocados, salad vegetables, cheese, or eggs are not listed in the tables because these foods contain little or no carbohydrates.

Brand-Miller et al (1996) set the following values for low, medium and high GI foods, based on glucose as the reference food as: Low GI = 55 or less, Medium GI = 56-69 and, High GI = 70 or more.

The 2002 International Table of Glycemic Index and Glycemic Load Values, list the average GI value for orange juice as 52 and grapefruit juice as 48, based on glucose as the reference food. According to Brand-Miller et al (1996), orange juice and grapefruit juice would be classified as low GI value foods.

In 1997, a joint experts committee of the Food and Agriculture Organization (FAO) and World Health Organization (WHO) reviewed the available research evidence regarding the importance of carbohydrates in human nutrition and health. The committee endorsed the use of the GI method for classifying carbohydrate rich foods and recommended that the GI values of foods be used in conjunction with information about food composition to guide food choices (FAO/WHO, 1997).

The report further stated that some low GI foods might not always be a good choice because they are high in fat. Conversely, some high GI foods may be a good choice because of convenience or because they have low energy and high nutrient content. It is not necessary or desirable to exclude or avoid all high GI foods. In order to promote good health, the committee advocated the consumption of a high-carbohydrate diet (greater than 55% of energy from carbohydrate), with the bulk of carbohydrate-containing foods being rich in non-starch polysaccharides (NSP) with a low GI (FAO/WHO, 1997).

The 2005 Dietary Guidelines for Americans published by the US Department of Health and Human Services states that carbohydrates are part of a healthful diet. The acceptable macronutrient distribution ranges (AMDR[b]) for carbohydrates is 45 to 65% of total caloric intake. In a 2,000 calorie diet, 900 to 1,300 calories could be provided by carbohydrates. Carbohydrates can be naturally present in foods or be added to them during processing and preparation. Although the body response to them is the same, it should be emphasized that naturally containing sugar foods, as fruit and vegetables are source of many nutrients. Therefore, they can promote health and reduce chronic disease risk. The 2005 Dietary Guidelines (USHHS[c], 2005) states that the inclusion of orange juice can help meet recommended levels of potassium intake. An 8 oz. glass of orange juice (unsweetened) provides only 105 to 112 calories and provides significant amounts of vitamins and minerals (Gebhardt & Thomas, 2002).

[b]Acceptable Macronutrient Distribution Ranges (AMDR): Range of intake for a particular energy source that is associated with reduced risk of chronic disease while providing intakes of essential nutrients. If an individual consumes in excess of the AMDR, there is a potential of increasing the risk of chronic diseases and/or insufficient intakes of essential nutrients.

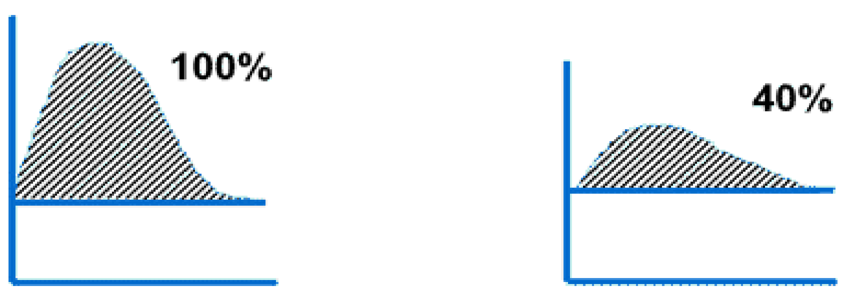
[c] USHHS: United States Department of Health and Human Services.

2.3 – Glycemic index methodology:

A typical determination of the GI value for a food includes feeding volunteers a portion of food that contains 50 grams of available carbohydrates, and then measuring the effect on their blood glucose levels over the next two hours for each person. The area under the curve (AUC) of their two-hour blood glucose response for this food is measured. On another occasion, the same participants consume an equal-carbohydrate portion of glucose (reference food) and their two-hour glucose response is also measured. A GI value for the test food is then calculated for each participant, by dividing their AUC for the test food by the AUC for the reference food. The final GI value for the test food is the average GI value for the total number of participants. An example for the two-hour blood sugar response for glucose (reference food) and lentils is shown in figure 1.

Figure 1 - The two hour blood sugar response of glucose and lentils

Reference food **Test food**



Glucose, GI score = 100 Lentils, GI score = 40

The amount of carbohydrate (starch & sugars) in the reference and test foods must be the same.

Source: Revised from University of Sidney: http://www.glycemicindex.com/aboutGI.htm

The specific methodology for determining a food's GI, used by the Glycemic Index Laboratories Inc. in Toronto, Canada can be found in appendix A of this report.

Some laboratories use white bread as the reference food for measuring GI values while others use glucose. If glucose is used, its GI value is 100 and the GI value for white bread is 70. If white bread is used as the reference food, its GI value is 100 and that of glucose is 137 (Foster-Powell et al, 2002).

The use of different reference foods leads to conflicting published values for GI. In addition, 50 g of carbohydrates in white bread is more difficult to determine accurately than is 50 g of glucose (Pi-Sunyer, 2002). Differences in testing methods include the use of different types of blood sampling methods: capillary versus venous. Although capillary and venous blood glucose values have been shown to be highly correlated, it appears that capillary blood samples may be a more relevant indicator for reliable GI testing. After the consumption of a food, glucose concentrations change to a greater degree in capillary blood samples than in venous blood samples. Therefore, capillary blood samples may be a more relevant indicator of the physiological consequences of high GI foods. Other factors that can lead to differences in GI values include different experimental time periods, and a variety of serving sizes (Foster-Powell et al, 2002).

Pi-Sunyer (2002) pointed out several factors affecting the reproducibility of the GI that would limit the use of GI as a nutritive marker for dietary recommendation. The ripeness of the fruit is among those factors, as a fruit ripens, starch is changed to sugar, so as ripeness progresses, the GI decreases. Changing the particle size of some foods changes their GIs. Consumption of apples as whole, puree or juice results in different glucose excursions. The proportion of amylase to amylopectin in the grains affects the GI of rice. Thus, 50 g equivalents of different rices produce GIs ranging from 68 to 103. Pasta also produces different GIs, within a class of pasta, a different thickness will result in a different GI. The method of processing of a single food can also change its GI, as application of heat and moisture affects starch granules. GI is dependent on the history of the processing, storing, ripening, cutting and cooking of the food. Studies have also shown that a mixed meal of carbohydrate, protein and fat will have a different and variable glucose response depending on the proportions of each nutrient. An increase in the acidity of a meal could greatly lower its GI. Orange juice is an acid food whose pH normally ranges between 3.4 and 4.0, and therefore its effect on the GI of a mixed meal should be investigated.

2.4- Glycemic Load

Salmeron et al (1997) introduced the concept of Glycemic Load (GL) to quantify the overall glycemic effect of a portion of food. The GL of a typical serving of food is the product of the amount of available carbohydrate in the serving, and the GI of the food. The higher the GL, the greater the expected elevation in blood glucose and insulin response to the food.

There is some controversy concerning the value of GL data. In many cases, GL is not based on a normal or typical amount of food or drink ingested, so GL does not provide realistic information, unless the food is weighed prior to consuming it. The value of GL is that it provides an understanding of the relationship between specific amount of food and its glycemic response.

The GL values can be applied to mixed meals or whole diets by calculating the weighted GL value (GL) of the meal or diet. Below is an example of a breakfast meal containing bread, cereal, sucrose, milk and orange juice. The individual food's GI values are based on glucose = 100.

Table 2 – Glycemic index and glycemic load of a meal

Food	Grams Glycemic Carbohydrate	Proportion of total Glycemic Carbohydrate	Food Glycemic Index	Meal Glycemic Load *
Bread	25	0.298	70	20.9
Cereal	25	0.298	50	14.9
Milk	6	0.071	27	1.9
Sucrose	5	0.060	61	3.6
Orange juice	23	0.274	52	14.2
TOTAL	**84**			**55.5**

Source: Modified from FAO/WHO, 1997

* Values for GL of each food equals the proportion of total glycemic carbohydrate multiplied by the food GI. The sum of these values is the meal GL.

Using this type of calculation, there is a good correlation between meal GL and the observed glycemic responses of meals of equal nutrient composition.

Additional breakfast menus containing orange juice as a component can be found in appendix C. The GI values for the various menus has been calculated and in four cases the orange juice component has been lowered from an 8 oz serving to a 6 oz serving in order to determine the effect on the total meal GL. In these typical American breakfast menus the lowering of the intake of OJ actually increased the total meal's GL. This unexpected result is due to at least one of the additional meal components having a significantly higher GI than that found in orange juice therefore yielding a higher percentage of total carbohydrates to the meal. The total meal GIs have been characterized as either being a high, medium or low as set by Brand-Miller et al (2003).

Brand-Miller et al (2003) states the following range of values for low, medium and high GL values for individual foods: Low GL = 10 or less, Medium GL = 11-19 and High GL = 20 or more. A typical diet has approximately 100 GL units per day (range 60-180).

The GI, and GL values for citrus fruits and juices are shown in appendix D of this report. The GL values listed in the table are based on GI having glucose as a reference food. According to the table in appendix D, orange juice would be classified as a medium GL value food.

3. Epidemiological and Clinical Studies

The clinical relevance of GI has been vigorously debated in recent years. Some epidemiological and clinical studies have examined the relationship between GL and chronic diseases.

Salmeron et al (1997) found that diets with a low GL and a high (> 8.1 g/day) cereal fiber content reduced risk of NIDDM (Non-Insulin-Dependent Diabetes Mellitus – type 2 diabetes) in men compared to men with high GL intake and low (3.2 g/day) cereal fiber content diet. Further, they suggest that grains should be consumed in a minimally refined form to reduce the incidence of NIDDM.

Liu et al (2000) used data from the Nurses' Health Study initiated in 1976 to evaluate the relationship of the amount and type of carbohydrates with risk of coronary heart disease (CHD). The Nurses' Health Study is a longitudinal study of diet and lifestyle factors in relation to chronic diseases among 121,700 female registered nurses' ages 30-55 year at enrollment. The data used by Liu et al (2000) came from the same population but excluded women who had been previously diagnosed with diabetes and cardiovascular disease (including angina, myocardial infarction, stroke and CHD. In total, over 75,000 participants aged 38-63 were used in this follow-up study. The measurements of dietary intake were repeated in 1986 and 1990 using almost identical 126-item semi quantitative food-frequency questionnaire. The study found a significant positive association between dietary GL and risk of coronary heart disease. Results also showed that women with high dietary GLs, consumed more carbohydrates, dietary fiber, cereal fiber, vitamin E, and folate, and they also had lower intakes of fats, cholesterol, proteins, and alcohol and smoked less than did women with low dietary GLs. Additional results showed that higher GL did not appear to affect risk of CHD among women with low body mass index (BMI).

In an independent study by Willett et al (2002) the relationship of GI, GL and the risk of type 2 diabetes were studied. Data from both the Nurses' Health Study and the men's Health Professional's Follow-up Study were evaluated. The men's Health Professional's Follow-up Study is a longitudinal study of diet and lifestyle factors in relation to chronic diseases among 51,429 health professional men who were 40-75 years of age at 1986. The data from 42,759 men without NIDDM or cardiovascular disease (CVD) were used by Willett et al (2002). After adjustment for age, BMI, alcohol intake, physical activity, and cereal fiber intake in women in the highest quintile of GL had a 40% greater risk of diabetes than did women in the lowest quintile. It was also noted that women with low cereal fiber intake and high GL intake had a 2.5-fold higher risk of diabetes than those with high intake of cereal fiber and low dietary GL intake. Similar relationships were seen among the men participating in Health Professional's Follow-up Study (Willet et al 2002).

The results from the Nurses' Health Study and the men's Health Professional's Follow-up Study as related to the influence of the GI and GL as a key factor for the prevention of diabetes, CVD and obesity has been questioned by Pi-Sunyer (2002).

Pi-Sunyer states that by its nature, an epidemiologic study can detect an association between two variables but cannot prove causation. Although a certain amount of evidence can be accrued from investigations using animal models, epidemiologic studies, and clinical investigations, only controlled clinical trials can provide proof of causality.

In the 2003 report from a Joint FAO/WHO Expert Consultation (FAO/WHO, 2003) low glycemic foods have been proposed as a potential protective factor[d] against weight gain. Even though there are some studies that support this hypothesis, more clinical trials are needed to establish the association with greater certainty. The report emphasizes the need to improve the quality of diets by increasing consumption of fruits and vegetables, in addition to increasing physical activity in order to stem the epidemic of obesity and associated diseases. Overweight and obesity are associated with an increased risk of type 2 diabetes. The most dramatic increases in type 2 diabetes are occurring in societies in which there have been major changes in the type of diet consumed, reductions in physical activity and increases in obesity. Evidence that saturated fatty acids increase risk of type 2 diabetes and that NSP are protective is more convincing than the evidence for several other nutrients. In human intervention studies, replacement of saturated by unsaturated fatty acids leads to improved glucose tolerance and insulin sensitivity (Uusitupa et al, 1994). However, when total fat intake is high (greater than 37% of total energy), altering the quality of the dietary fat has little effect. A high total fat intake has been associated with higher fasting insulin concentrations and a lower insulin sensitivity index (Lovejoy & DiGirolamo, 1992).

Low GI foods, regardless of their NSP content, are associated with a reduced glycemic response after ingestion when compared with foods of higher GI and are also associated with an overall improvement in glycemic control. A low GI does not, however, per se, confer overall health benefits, since a high fat or high fructose content of a food may also result in a reduced GI and such foods may also be energy-dense.

According to Daly (2003), the evidences for negative health effects of high-GL diets come from studies in which starches rather than sugars provided the major component of the overall GL. Research on animals, particularly rodents, has shown a clear and consistent effect of high-sucrose and high-fructose diets in decreasing insulin sensitivity. Experiments in humans have produced very conflicting results, with limited evidence for a negative effect on insulin sensitivity at higher intakes of fructose or sucrose. There is a possibility that sucrose may affect insulin sensitivity only with a high fat intake (Daly, 2003).

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[d]Possible evidence: Evidence based mainly on findings from case-control and cross-sectional studies. Insufficient randomized controlled trials; observational studies or non-randomized controlled trials are available. Evidence based on non-epidemiological studies, such as clinical and laboratory investigations, is supportive. More trials are required to support the tentative associations, which should also be biologically plausible.

Basciano et al (2005) reported that increasing evidence suggests that the rise in consumption of carbohydrates, particularly refined sugars high in fructose, appears to be at least one very important contributing factor to increased insulin resistance. A high flux of fructose (85 – 100g/day) to the liver disturbs normal hepatic carbohydrate metabolism leading to two major consequences: perturbations in glucose metabolism and a significantly enhanced rate of lipogenesis and triglycerides syntheses. Those factors contribute to reduced insulin sensitivity and hepatic insulin resistance/glucose intolerance. Interestingly, small quantities of fructose can have positive effects, and actually decrease the glycemic response to glucose loads, and improve glucose tolerance.

The amount, type (glucose versus fructose) and rate of digestion of dietary carbohydrate are the primary determinants of postprandial glucose and insulin responses. Fructose produces much lower glucose and insulin responses than glucose because it is slowly converted to glucose in the liver and only some of this glucose is released into the circulation (Wolever, 2000).

It is recognized that higher intakes of free sugars threaten the nutrient quality of diets by providing significant energy without specific nutrients. The 2005 Dietary Guidelines recommends that it is important to choose carbohydrates wisely. Among the foods providing carbohydrates, orange juice is a nutrient dense, fat free food that provides for maintenance of good nutrition. Therefore, there is no scientific based evidence to exclude citrus juice as part of any healthy diet.

Due to the absence of specific information on the glycemic index and glycemic load of Florida orange juices, the Department of Citrus contracted with Glycemic Solutions, a professional clinical research organization, to determine the GI and GL of three commercially available 100% Florida orange juices. The juices evaluated were a premium not from concentrate juice, a premium not from concentrate with high pulp juice and a from concentrate juice.

The glycemic index was determined In Vivo utilizing the Glycemic Solutions standardized clinical protocol. Ten Non-Diabetic Human subjects were used for each product tested. White Bread was used as the standard. Each subject was fed a minimum of three bread standards for comparison to the product tested. Both a 4oz and an 8oz sample of each juice were evaluated to determine the GI and GL's associated with different levels of intake. Calculations were made using the area under the curve as compared to bread standards (converted to the glucose scale). The GL's for each of the three juices tested was calculated as previous describe in the paper. The results of the tests on the three juices appear in Table 3.

Table 3 - Glycemic Index/Glycemic Load Results

Orange Juice	Glycemic Index	Glycemic Load	Carbohydrates
NFC – 4 oz.	33	4.3	---
NFC – 8 oz.	48	12.5	26.1 g
NFC-high pulp – 4 oz.	34	4.5	---
NFC-high pulp – 8 oz.	47	12.5	26.7 g
From Concentrate – 4 oz.	27	3.6	---
From Concentrate – 8 oz.	48	12.9	26.9 g

Among the foods providing carbohydrates, orange juice is a nutrient dense, fat-free food that provides for maintenance of good nutrition. There is no scientific based evidence to exclude citrus juice as part of any healthy diet including most popular low-carbohydrate diets.

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Appendix A

Glycemic Index test Methodology: Glycaemic Index Testing Inc.

Ten (10) normal subjects are studied on multiple occasions (maximum 3 per week) in the morning after a 10-14h overnight fast. Subjects are asked to do no unusually vigorous activities on the day before the test, to drink no alcohol and not to smoke for 24h before the test. After a fasting blood sample, subjects eat a test meal and have further blood samples at 15, 30, 45, 60, 90 and 120 minutes after starting to eat. Capillary blood is obtained by finger-prick and whole blood glucose determined with an automatic analyzer using the glucose oxidase method.

Each test meal contains 50g available carbohydrate (total carbohydrate minus dietary fiber). Unavailable carbohydrates such as fructo-oligosaccharides, resistant starch and sugar alcohols are not included as available carbohydrate. The GI is valid as a method of classifying the blood glucose responses of high carbohydrate foods. To test low carbohydrate foods, meals containing smaller amounts of carbohydrate may be used, but the amount of reference food should be adjusted so that it contains the same amount of available carbohydrate as the reference food. However, the interpretation of the GI values obtained is unclear.

A drink of the subject's choice is served with each test meal. The subject can chose to have 1-2 cups of water, coffee or tea, with 30ml 2% milk per cup if desired. However, the drink chosen by the subject is the same for every test performed. Test meals are consumed within 10 minutes.

Each subject conducts one trial of each test food and 3 trials of the reference food. The reference food can be anhydrous glucose or white bread (baked from weighed ingredients so its composition is exactly known). Other reference foods could be used (eg. maize meal) provided that its GI relative to glucose is well established (and periodically monitored to ensure no changes) so that the resulting GI values can be adjusted to the glucose scale. Typically the reference food trials are done at the beginning middle and end of the series of tests, with the order of the test foods randomized between the reference foods. If large numbers of foods are being tested, a reference food trial should be done for every 5-6 test foods (to ensure no changes in subject's glucose responses with time).

Calculation of Area Under the Curve (AUC)

There are many ways to calculate the AUC, and the method used affects the GI value obtained. The correct method for GI is shown below.

Assuming that at times t_0, t_1, ... t_n (here equalling 0, 15 ... 120 min, respectively) the blood glucose concentrations are G_0, G_1, ... G_n, respectively.

$$AUC = \sum_{n}^{x=1} A_x$$

Where A_x = the AUC for the xth time interval and the xth time interval is the interval between times $t_{(x-1)}$ and t_x.

For the first time interval (ie. X=1):

if $G_1 > G_0$, $A_1 = (G_1 - G_0) \times (t_1 - t_0)/2$ otherwise, $A_1 = 0$

For other time intervals (ie. X>1):

if $G_x > G_0$ *and* $G_{(x-1)} > G_0$, $A_x = \{[(G_x - G_0)/2] + (G_{(x-1)} - G_0)/2\} \times (t_x - t_{(x-1)})$

if $G_x > G_0$ *and* $G_{(x-1)} < G_0$, $A_x = [(G_x - G_0)^2/(G_x - G_{(x-1)})] \times (t_x - t_{(x-1)})/2$

if $G_x < G_0$ *and* $G_{(x-1)} > G_0$, $A_x = [(G_{(x-1)} - G_0)^2/(G_{(x-1)} - G_x)] \times (t_x - t_{(x-1)})/2$

if $G_x < G_0$ *and* $G_{(x-1)} < G_0$, $A_x = 0$

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Appendix B

Glycemic Index Testing Laboratories

1. **Glycemic Solutions Clinical Research**

   100 Second Avenue South
   Suite 200 South Tower
   St. Petersburg, Florida 33701
   USA

2. **Glycaemic Index Testing Inc**.

   5 Queen Street East, Suite 207
   Toronto, Ontario M5C 1R6 Canada
   Telephone: 416-214-5971

3. **The International Diabetes Institute (IDI**)

   250 Kooyong Road
   Caulfield, Vicotria 3162 Australia

4. **Sydney University GI Research Service (SUGiRS**

   Human Nutrition Unit
   Department of Biochemistry (GO8)
   Sydney University
   NSW 2006, Australia

Appendix D

Glycemic Index, and Glycemic Load values of Citrus Fruit and Juices *

Food Number and item	GI (Glucose =100)	GI (Bread =100)	Reference food and time period	Serving size (*g*)	Available carbo-hydrate *g/serving*	GL (per serving)
40 Grapefruit juice, unsweetened (Sunpac, Toronto, Canada	48	69± 5	Bread, 3 h	250 mL	22	11
41 Orange Juice						
Orange Juice (Canada)	46±6	66	Glucose, 2 h			
Orange Juice, unsweetened, recon. (Quelch; Berri Ltd, Carlton, Australia	53±6	76	Bread, 2 h			
Mean of two studies	**50±4**	**71±5**		**250 mL**	**23**	**16**
407 Grapefruit, raw (Canada)	25	36	Glucose,	120	11	3
408 Grapefruit juice, unsweetened (Sunpac, Toronto, Canada	48	69± 5	Bread, 3 h	250 mL	20	9
415 Oranges, raw						
Oranges, NS (Denmark)	31	44±13	Bread, 3 h	120	11	3
Oranges, NS (South Africa)	33±6	47	Glucose, 2 h	120	10	3
Oranges, NS (Canada)	40±3	57	Glucose, 2 h	120	11	4
Oranges, NS (Italy)	48	68±	Bread, 2 h	120	11	5
Oranges, **(Sunkist, Van Nuys, Ca, USA**)	48	69±11	Bread, 3 h	120	11	5
Oranges, (Canada)	51	73	Glucose, NS	120	11	6
Mean of 6 studies	**42±**	**60±5**		**120**	**11**	**5**
416 Orange Juice						
Orange Juice (Canada)	46±6	66	Glucose, 2 h	250 mL	26	12
Orange Juice, unsweetened, recon. (Quelch; Berri Ltd, Carlton, Australia)	53±6	76	Bread, 2 h	250 mL	18	9
Orange Juice, reconstituted from frozen	57±6	81±8	Glucose, 5 h	250 mL	26	15
Mean of 3 studies	**52±3**	**74±4**		**250mL**	**23**	**12**

- Data presented on this table was taken from the *International table of glycemic index and glycemic load values:2002* by Kaye Foster-Powell, Susanna Holt and Janette C Brand-Miller. Previously referenced.

Appendix C

Breakfast Menus

Meal Description[A]	Serving Size[A]	Comments[D]	Glycemic Index (GI) (glucose =100)[B]	Available carbohydrates[B]	% of Total meal carbs by item	Glycemic Index (GI) of meal by item	GI rating of meal H=High, M=Medium, L=Low [C]
Meal 1							
High fiber low sugar cereal (e.g., 100% Bran Flakes, Raisin Bran)	1 cup	59 g/serving[A]	61	38	53.90%	32.9	
Fat-free milk	1/2 cup (4 fluid oz)		32	6.5	9.22%	3.0	
Strawberries	1/2 cup sliced	120 grams	40	3	4.26%	1.7	
100% orange juice	1 cup (8 fluid oz)		52	23	32.62%	17.0	
Total Carbs in Meal				**70.5**			
Glycemic Index of Meal						**54.5**	**L**
Meal 2							
Low fiber high sugar cereal (e.g., Cocoa Puffs)	1 cup		77	52	59.77%	46.0	
Whole milk	1 cup (8 fluid oz)		27	12	13.79%	3.7	
100% orange juice	1 cup (8 fluid oz)		52	23	26.44%	13.7	
Total Carbs in Meal				**87**			
Glycemic Index of Meal						**63.5**	**M**
Low fiber high sugar cereal (e.g., Cocoa Puffs)	1 cup		77	52	64.20%	49.4	
Whole milk	1 cup (8 fluid oz)		27	12	14.81%	4.0	
100% orange juice	1 cup (**6 fluid oz**)		52	17	20.99%	10.9	
Total Carbs in Meal				**81**			
Glycemic Index of Meal						**64.3**	**M**

Meal 3

Oatmeal, quick cook oats	1 cup prepared	243 grams	66	23	50.00%	33.0	
Bacon, regular, fried	3 slices		0	0	0.00%	0.0	
100% orange juice	1 cup (8 fluid oz)		52	23	50.00%	26.0	
Total Carbs in Meal				**46**			
Glycemic Index of Meal						**59.0**	**M**

Meal 4

Toast, whole wheat bread	1 slice	Whole Wheat snack bread	74	22	29.33%	21.7	
Margarine	2 teaspoons		0	0	0.00%	0.0	
Yogurt, low fat, fruit flavored (strawberry)	1 container (8 oz net wt)		31	30	40.00%	12.4	
100% orange juice	1 cup (8 fluid oz)		52	23	30.67%	15.9	
Total Carbs in Meal				**75**			
Glycemic Index of Meal						**50.1**	**L**

Meal 5

Bagel, regular	1 large (4-4½" diameter)	70 grams	72	35	60.34%	43.4	
Cream cheese, plain	2 Tablespoons		0	0	0.00%	0.0	
100% orange juice	1 cup (8 fluid oz)		52	23	39.66%	20.6	
Total Carbs in Meal				**58**			
Glycemic Index of Meal						**64.1**	**M**

Bagel, regular	1 large (4-4½" diameter)	70 grams	72	35	67.31%	48.5	
Cream cheese, plain	2 Tablespoons		0	0	0.00%	0.0	
100% orange juice	1 cup (**6 fluid oz**)		52	17	32.69%	17.0	
Total Carbs in Meal				**52**			
Glycemic Index of Meal						**65.5**	**M**

Meal 6 (fast food)

English muffin sandwich		4.9 ounces, 138 grams (from McDonalds Web site)					
English muffin	1 muffin	2 ounces (from McDonalds Web site) (52 g)	77	24	31.58%	24.3	
Egg, fried	1 egg		0	0	0.00%	0.0	
Canadian bacon	1 slice		0	0	0.00%	0.0	
Processed American cheese	1 slice		0	0	0.00%	0.0	
Hash browns	1 serving	1.9 ounces, 53 grams (from McDonalds Web site)	75	29	38.16%	28.6	
100% orange juice	1 cup (8 fluid oz)		52	23	30.26%	15.7	
Total Carbs in Meal				**76**			
Glycemic Index of Meal						**68.7**	**M**

English muffin sandwich		4.9 ounces, 138 grams (from McDonalds Web site)					
English muffin	1 muffin	2 ounces (from McDonalds Web site) (52 g)	77	24	34.29%	26.4	
Egg, fried	1 egg		0	0	0.00%	0.0	
Canadian bacon	1 slice		0	0	0.00%	0.0	
Processed American cheese	1 slice		0	0	0.00%	0.0	
Hash browns	1 serving	1.9 ounces, 53 grams (from McDonalds Web site)	75	29	41.43%	31.1	
100% orange juice	1 cup (**6 fluid oz**)		52	17	24.29%	12.6	
Total Carbs in Meal				**70**			
Glycemic Index of Meal						**70.1**	**M**

Meal 7							
Scrambled eggs	2 large eggs		0	0	0.00%	0.0	
Bacon, regular, fried	3 slices		0	0	0.00%	0.0	
Toast, white bread	1 slice		70	14	27.83%	19.5	
Strawberry jam	1 Tablespoon	20 grams	34	13.3	26.44%	9.0	
100% orange juice	1 cup (8 fluid oz)		52	23	45.73%	23.8	
Total Carbs in Meal				**50.3**			
Glycemic Index of Meal						**52.3**	**L**
Meal 8							
Doughnut, cake type	1 medium		76	23	50.00%	38.0	
100% orange juice	1 cup (8 fluid oz)		52	23	50.00%	26.0	
Total Carbs in Meal				**46**			
Glycemic Index of Meal						**64.0**	**M**
Doughnut, cake type	1 medium		76	23	57.50%	43.7	
100% orange juice	1 cup (**6 fluid oz**)		52	17	42.50%	22.1	
Total Carbs in Meal				**40**			
Glycemic Index of Meal						**65.8**	**M**
Meal 9							
Pancakes, buttermilk	2 pancakes (6" diameter)	108 grams	67	19	23.17%	15.5	
Butter or margarine	2 Tablespoons		0	0	0.00%	0.0	
Maple syrup	2 Tablespoons (40 gms)	Sucrose (88-99%)	68	40	48.78%	33.2	
Sausage, pork	2 patties		0	0	0.00%	0.0	
100% orange juice	1 cup (8 fluid oz)		52	23	28.05%	14.6	
Total Carbs in Meal				**82**			
Glycemic Index of Meal						**63.3**	**M**

[A] Menus and serving size developed by Ms. Gail Rampersaud, MS, RD, LD/N, University of Florida

[B] International Table of Glycemic Index and Glycemic Load values: 2002

[C] The New Glucose Revolution, Dr. Jennie Brand-Miller, University of Sydney: Low GI = 55 or less, Medium = 56-69, High = 70 or more

[D] Weight data obtained from Nutritive Value of Foods, USDA Home and Garden Bulletin Number 72, unless otherwise