REVIEW OF GLUCOSE CONTROL, GI AND TYPE 2 DIABETES WITH A FOCUS ON FRUIT JUICE

1. GLYCEMIC RESPONSE

Glycemic response refers to the effect that foods and drinks have on blood glucose after consumption. After eating a meal, carbohydrates (excluding fibre) are absorbed from the intestine into the bloodstream, causing a temporary increase in blood glucose concentration – this is called a glucose excursion. In response, the hormone insulin is released and blood glucose concentration returns to fasting levels, or may fall slightly below.

There is clear scientific evidence that persistent elevation of blood glucose is linked with conditions such as type 2 diabetes, cardiovascular disease and obesity. A systematic review and meta-analysis confirmed that diets with a low glycemic impact (i.e. resulting in only moderate elevations of blood glucose) have a role in reducing the risk of such chronic conditions[1].

There are several markers for assessing glycemic status, all of which are used to diagnose diabetes[2]. Normal and abnormal values are shown in Table 1.

- Fasting blood glucose levels
- Oral Glucose Tolerance Test (OGTT), which measures how quickly a 75 g dose of glucose is cleared from the blood in a fasting individual
- Concentrations of glycated proteins e.g. HbA1c, which reflect the impact of long-term elevations in blood glucose.

Table 1: Glycemic control markers criteria[3]

Marker	Normal	Diabetes
Fasting glucose	70–99 mg/dl (3.9–5.5 mmol/l)	≥ 126 mg/dl (7.0 mmol/l)
OGTT	< 140 mg/dl (7.8 mmol/l)	≥ 200 mg/dl (11.1 mmol/l)
HbA1c	< 6.5%	≥ 6.5 %

The glycemic effect of foods also depends on the sensitivity of tissues to **insulin**, a hormone secreted by the pancreas. When released, this stimulates insulin-sensitive tissues, such as muscle and adipose tissue, to take up glucose from the blood. As blood glucose returns to normal, insulin release is slowed to normal resting levels.

In cases of 'insulin resistance', muscle and adipose tissue do not respond adequately to insulin production. This results in a reduced rate of glucose uptake from blood with the consequence that blood glucose levels remain elevated. More insulin is then released leading to chronically high plasma insulin levels. In the long term, there is a risk that the pancreas may become exhausted, resulting in falling insulin levels and a need for insulin administration.

The homeostatic model assessment (HOMA) is often used to assess the risk of insulin resistance. This marker shows the dynamic between baseline (fasting) blood glucose and the responsive hormone insulin; the healthy range is 0.5–1.4.

2. GLYCEMIC INDEX (GI)

Carbohydrates provide a significant energy source in our diets. The glycemic response depends on the type of carbohydrate and its molecular composition. In addition, GI is influenced by the food matrix in which the carbohydrates are present. The matrix, in turn, is influenced by food processing and the presence of dietary fibre, protein and fat. Carbohydrate-containing foods that result in a slow increase in blood glucose may be called low glycemic foods.

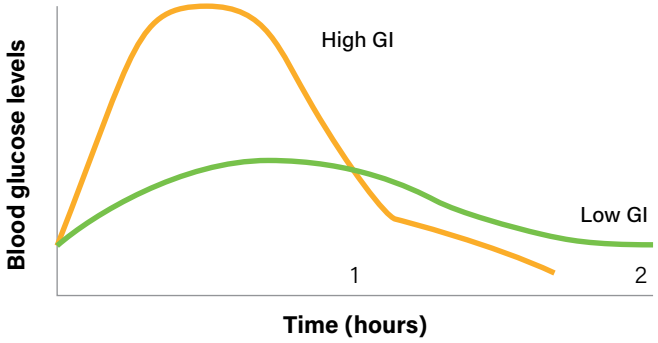
Pure glucose is rapidly taken up by the bloodstream and is given a standard glycemic value of 100. By comparing carbohydrate foods to this standard of 100, it is possible to give these a relative index score. In this respect, GI is defined as the area under the glucose response curve after consumption of 50 g carbohydrate from a test food divided by the area under the curve after consumption of 50 g glucose (sometimes white bread is taken as standard, instead of glucose)[4].

Generally, there are three categories of foods based on their GI values[5]:

- high GI foods (≥ 70)
- intermediate GI foods (56–69)
- low GI foods (≤ 55)

Consuming low GI foods, instead of high GI foods, has a positive effect on keeping post-meal glucose excursions and related insulin requirements relatively low (Fig. 1). Fully and readily digestible carbohydrates, such as glucose, maltodextrin, white bread and cooked potato starch, produce a rapid increase in blood glucose and insulin, followed by an equally rapid fall. If high GI foods are eaten in significant amounts, this has implications for the overall glycemic impact of the meal. Consuming high glycemic meals frequently in conditions of overweight and inactivity will drive the development of insulin resistance and type 2 diabetes.

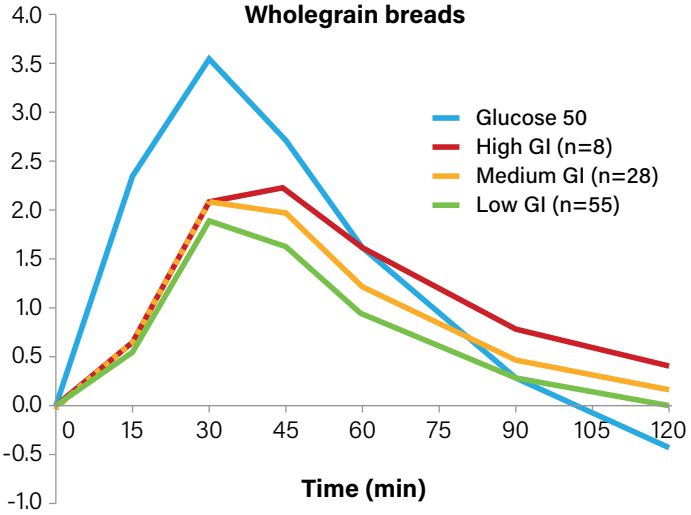
Figure 1: Blood glucose response in healthy adults[6]

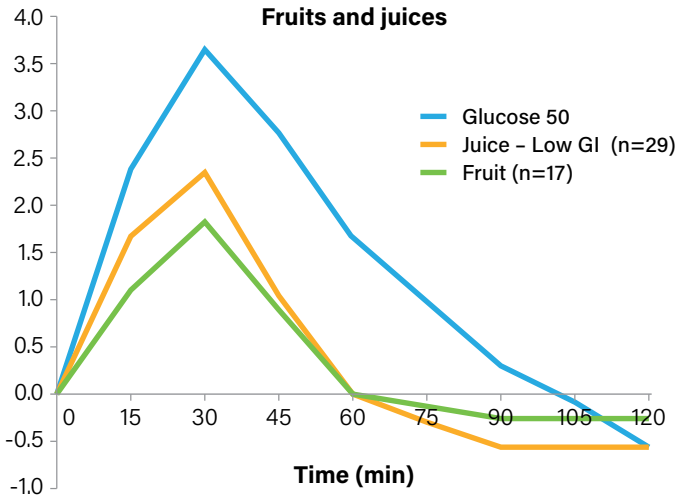


Legend: *After a high glycemic meal there is a rapid increase in blood glucose. This triggers a significant insulin release which stimulates tissues to take up glucose from blood. As a result, the blood glucose level will fall rapidly, sometimes even below the pre-meal level (hypoglycemic effect). In contrast, consumption of a low glycemic meal will produce a moderate increase in blood glucose and insulin, and a slow return to the pre-meal blood glucose level.*

Consumption of fructose, for example found in fruits, table sugar, honey and fruit juices, only minimally increases blood glucose, explaining why fructose-containing foods tend to have a relatively low glycemic response. This is also the reason why 100% fruit juices have a low GI, contrary to popular belief and media claims that they produce a significant rise in blood glucose (Fig 2.)[7].

Figure 2: Examples of plasma glucose curves (mmol/l) after different food challenges





3. GLYCEMIC LOAD (GL)

The glycemic response to a food depends not just on GI but also on the total carbohydrate ingested. On this basis GL was created; defined by how much each portion of carbohydrate raises blood glucose levels. GL is classified as: low (≤ 10), intermediate (11–19) and high (≥ 20). Fruits and 100% fruit juices have a low GI and intermediate GL (Table 2).

Table 2: GI/GL of typical products[8]

Food item	GI/100 g	GL/portion
White bread	75+2	11/30 g
Whole wheat bread	74+2	7/30 g
Cornflakes	81+6	21/30 g
White rice, boiled	73+4	28/150 g
Apple, raw	36+2	6/120 g
Orange, raw	43+3	4/120 g
Orange juice, medium	50+2	11/250 ml
Orange juice, small	50+2	7/150 ml
Banana, raw	51+3	11/120 g
Potato, boiled	78+4	21/150 g
Sugar-sweetened drinks	63-68	16-23/250 ml

A systematic review and meta-analysis[1] of data from 45 studies reported that diets comprised of low glycemic foods reduced fasting blood glucose and HbA1c, particularly in people with poor fasting blood glucose control. Adding non-digestible carbohydrates enhanced these effects. Lower GL was more important than GI for lowering triglyceride levels.

4. 100% FRUIT JUICE, GLYCEMIC CONTROL AND TYPE 2 DIABETES

In one trial, 36 overweight subjects with raised plasma cholesterol were enrolled in a randomised, single-blinded, placebo-controlled clinical study[9] to investigate the metabolic effects of daily 100% orange juice consumption. During the 12-week intervention, participants received either 250 ml of orange juice or a control orange drink matched for energy and sugars. The results revealed that 100% orange juice had no adverse effects on insulin sensitivity (HOMA-IR), blood lipid profile or body weight. The authors concluded that: "Daily consumption of 250 ml of orange juice for three months did not result in an increase in dietary sugars intake in a cohort of overweight men with elevated total cholesterol concentration, and, despite media concern, an increase in body weight or decreased insulin sensitivity did not occur over the intervention".

A meta-analysis[10] of 12 randomised controlled trials involving over 400 participants who were obese or had risk factors for diabetes or cardiovascular disease examined the effect of sugar-containing beverages on fasting glucose and insulin levels. In half of these

studies, the intake of 100% fruit juice was 400 ml per day or more. The overall results showed that consumption of 100% fruit juices had no significant effect on fasting blood glucose or insulin levels.

Another meta-analysis[11] of four cohorts of adults found that consumption of fruit drinks with added sugars was significantly associated with an increased risk of type 2 diabetes (RR = 1.28: p = 0.02) while consumption of 100% fruit juices (i.e. no added sugars) had no effect (RR = 1.03, p = 0.62).

The most recent systematic review and meta-analysis[12], based on 18 randomised and controlled studies, examined the effects of 100% fruit juice on glucose-insulin homeostasis. Compared with controls, 100% fruit juices had no significant effect on fasting blood glucose (mean difference: -0.13 mmol/l; 95% CI -0.28, 0.01; p=0.07), fasting blood insulin (-0.24 mmol/l; 95% CI -3.54, 3.05; p=0.89), HOMA-IR (-0.22; 95% CI -0.50, 0.06; p=0.13) or HbA1c (-0.001%; 95% CI -0.38, 0.38; p=0.28). The authors concluded that their meta-analysis suggested: "a neutral effect of 100% fruit juice on glycemic control" and, consequently, "consumption of 100% fruit juice is not associated with increased risk of diabetes".

5. CONCLUSION

Overall, the available evidence shows clearly that 100% fruit juices have no negative effects on glucose-insulin homeostasis and are not a causal factor in the development of type 2 diabetes. This probably reflects the fact that 100% fruit juices have a low GI and contain significant amounts of bioactive components, such as flavanones, that have been shown to exhibit lipid-lowering, insulin-sensitising, antihypertensive and anti-inflammatory properties[13]. This may also explain the observation that a high intake of 100% orange juice and sugar-sweetened beverage, matched for energy and sugars, differently affects metabolic risk in healthy subjects[14].

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