# INNOVATIVE INGREDIENTS TO ADDRESS GLYCAEMIC RESPONSE

MAKING FOOD EXTRAORDINARY

TATE & LYLE

In light of the public health concerns surrounding high incidence of diabetes and metabolic syndrome there is a critical need to manage blood glucose. The food and beverage industry can play an immense role in developing products which will serve this need via designing products to have a lower glycaemic response. This document will review:

- The size of diabetes epidemic
- The importance of managing blood glucose
- The role of dietary interventions
- Specific ingredients that can help reduce the blood glucose response in food products such as fibres, rare sugars, and low and non-nutritive sweeteners (NNS)

## Defining glycaemic response

Various terms used to describe blood glucose changes can cause confusion. Table 1 details these definitions for numerous terms used to describe blood glucose - glycaemic response, glycaemic index, and glycaemic load. In this document, we will be referring to the clinical endpoint of glycaemic response.

**Table 1. Definitions of terms used to describe blood glucose responses to dietary components[1].**

| Glycaemic response (GR) | Glycaemic index (GI) | Glycaemic load (GL) |
|---|---|---|
| • Post-prandial blood glucose response caused when a food that contains carbohydrate is consumed.<br>• Also considered the change in blood glucose concentration over time and represented as the area under the curve (AUC). | • Representing quality of carbohydrate.<br>• % GR caused by a food containing 50 g of carbohydrate vs 50 g of the reference carbohydrate (glucose solution or white bread).<br>• Foods having carbohydrate that is digested, absorbed and metabolized quickly are considered high GI foods (GI ≥ 70) vs low GI foods (GI ≤ 55). | • GL = GI x available carbohydrate in a given amount of food<br>• Available carbohydrates, and GL, can be expresed as:<br>  • g per serving;<br>  • g per 100 g food;<br>  • g per day's intake;<br>  • g per 1000 kJ or 1000 kcal. |

# WHAT IS THE IMPACT OF DIABETES?

## Incidence

According to the World Health Organization (WHO) diabetes is a chronic metabolic illness with elevated levels of blood glucose, which if unmanaged, leads to impairment to the heart, blood vessels, eyes, kidneys, and nerves[2]. Type 1 diabetes occurs because the pancreas cannot produce any or sufficient amounts of the hormone insulin whereas in type 2 diabetes the body does not respond to insulin. Type 1 diabetes can occur at any age but most often starts in children and adolescents[3]. Type 2 diabetes is a chronic condition where the body does not utilize insulin properly which then impacts glucose metabolism. While type 2 diabetes was referred to as "adult-onset diabetes", it is occurring with increasing frequency in children and makes up the vast majority of diabetes cases[2].

The International Diabetes Federation (IDF) estimates that men have a slightly higher rate of diabetes than women and the age group 65-79 years has the highest prevelance[3]. Once an affliction of predominantly rich nations, Figure 1 demonstrates that type 2 diabetes has now spread to every region of the world[3]. Diabetes affected 425 million people worldwide or 8.8% adults in 2017 and is expected to rise to 629 million by 2045[3]. A significant challenge is that about 212 million or 50% of all adults with diabetes are undiagnosed[3]. The highest rates are found in North America and the Caribbean regions where 11.0%[i] of the population has diabetes compared to the Africa region at 4.2%, yet due to population sizes the largest numbers of are found in China, India, and then North America[3].

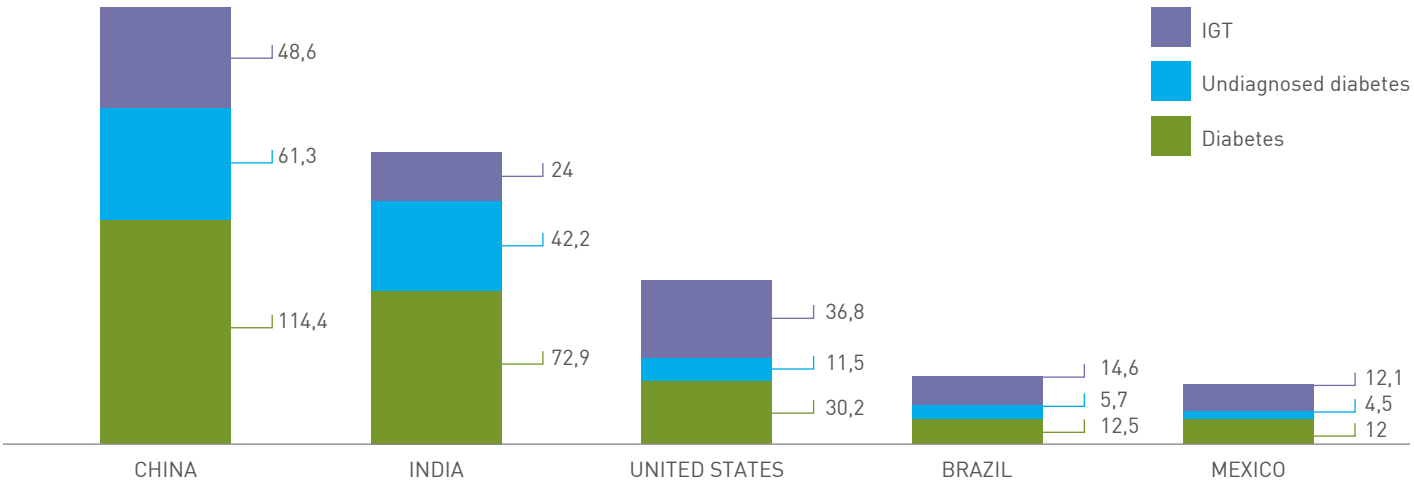
South and Central America fall in the middle of the global incidence rates with 7.6% of their population affected[3]. Prediabetes, or impaired glucose tolerance, is defined later in this document and affects 352.1 million people worldwide[3]. To indicate further what a serious health concern diabetes is, global estimates are that 212.4 million people are unaware that they have diabetes, which only adds numbers to a growing global epidemic[3].

## Global Burden of Diabetes

Diabetes is a complex disease that takes time and knowledge to manage. It affects people during critical stages of their education and productivity in the workplace, can reduce quality of life and even disable, reduces life expectancy, and eventually results in death if left unmanaged. In addition to real human costs, diabetes is associated with an enormous economic burden. Worldwide, diabetes is a costly problem demanding personal and families' finances for medical costs, drains national healthcare budgets, slows economic growth, and overwhelms healthcare systems[3]. Seventeen percent of the total healthcare budget was spent on diabetes in the Middle East and North African region, the highest percentage from all the regions that the IDF evaluated[4]. Global assessments for healthcare expenditures for adults with diabetes were USD 727 billion in 2017[3,4].

[i] Age-adjusted comparative diabetes prevalence

**Figure 1. Global incidence rates for the top five countries with the largest numbers (in millions) of adults with diagnosed diabetes, undiagnosed diabetes, or impaired glucose tolerance (IGT) in 2017[3].**




# WHAT CAUSES DIABETES?

## Physiology

Insulin is a hormone, secreted from the pancreas, but acts all over the body to maintain blood glucose as it signals cells to transport glucose. In type 1 diabetes, insulin is not produced, thus cells cannot absorb glucose resulting in hyperglycemia (high blood glucose) and serum glucose can be measured as a diagnostic tool, Table 2. In type 2 diabetes, the cells stop responding to insulin, termed insulin resistance, and this also results in high blood glucose. The fasting test is performed to measure the amount of glucose in the blood when someone has not eaten in at least eight hours and the impaired glucose tolerance (IGT) test measures the amount of glucose in the blood after someone drinks 75 grams of glucose, called a glucose response test (glucose tolerance test). Prediabetes is when blood glucose is higher than normal, but not elevated enough to be diagnosed as diabetes as a result of the IGT or impaired fasting glucose (IFG), table 2. Prediabetes occurs because of decreased insulin sensitivity or increased insulin resistance and symptoms are often milder versions of those with type 2 diabetes, Figure 2[5].

**Table 2. Diagnostic Criteria for Diabetes per the International Diabetes Foundation and WHO[3,4].**

| Test | Prediabetes | | Diabetes (any one of these results) |
|---|---|---|---|
| | Impaired Fasting Glucose° | Impaired Glucose Tolerance° | |
| Fasting Glucose* | 100-125 mg/dL (6.1-6.9 mmol/L) | < 126 mg/dL (< 7.0 mmol/L) | ≥ 126 mg/dL (≥ 7.0 mmol/L) |
| 2 hour glucose response** | 140-199 mg/dL (7.8-11.0 mmol/L) | ≥ 140 to < 200mg/dL (≥ 7.8 to < 11.1mmol/L) | ≥ 200 mg/dL (≥ 11.0 mmol/L) |
| Random Glucose test in symptomatic patient | N.A. | N.A. | ≥ 200 mg/dL (≥ 11.0 mmol/L) |
| HbA1c | N.A. | N.A. | ≥ 6.5% (≥ 48mmol/mol) |

° Both fasting glucose and 2 hour glucose response criteria should be met for prediabetes diagnosis. | *Fasting is defined as no calories for 8 hours before the blood test. | **Consumed as 75 g glucose dissolved in water. | **N.A.** Blood test not typically performed for this condition.

## Risk Factors

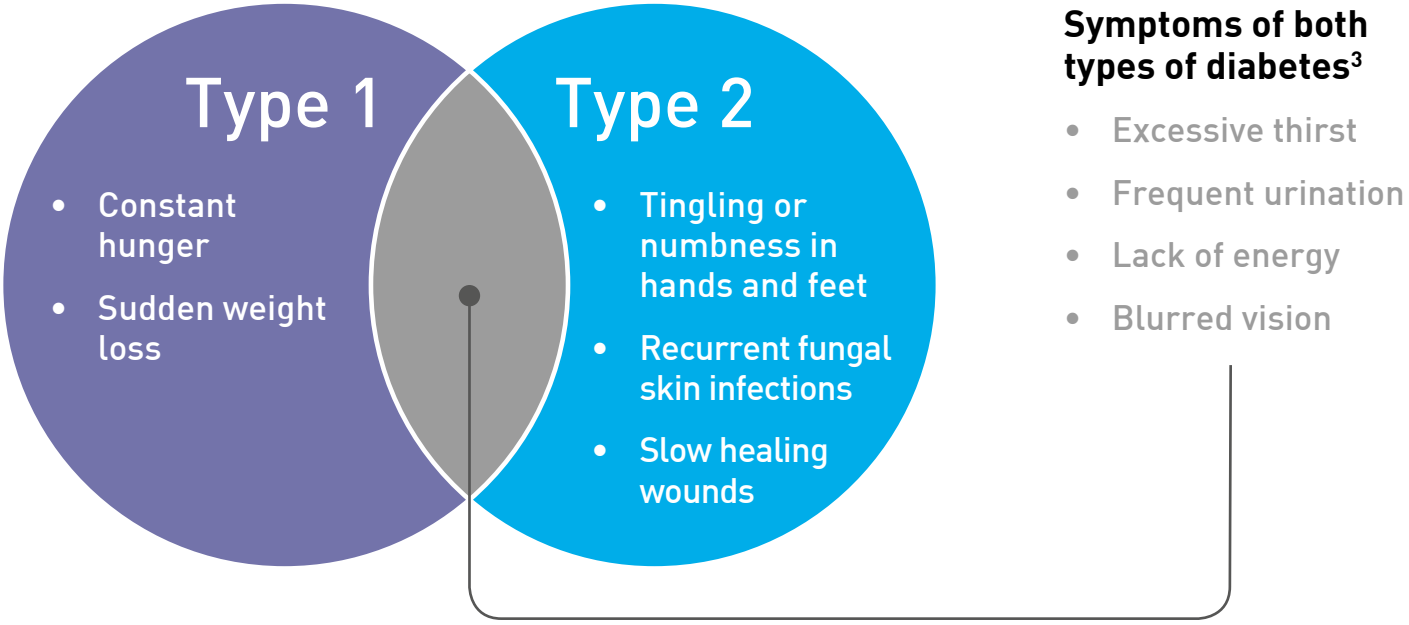
The risk factors for developing type 1 diabetes are family history, genetics, and infection, as shown in Table 3[6]. The incidence of type 1 diabetes is increasing and the cause is not definitive but could be due to global birth weights and life expectancy increasing[7]. Individuals with prediabetes are at high risk for developing insulin resistance and eventually type 2 diabetes[5]. Other risk factors for type 2 diabetes include physical inactivity, increased age, and a family history of diabetes, heart disease or stroke. One of the strongest risk factors for type 2 diabetes is being overweight or obese[8]. Estimates for 2016 indicated 1.9 billion adults were overweight, and of these 650 million were obese, and more than 340 million children and adolescents aged 5-19 years were overweight or obese[8]. In Asian or African populations even minor changes in body weight can have a significant impact on the risk of developing pre- or type 2 diabetes[9, 10, 11]. The risk factors with the greatest impact on the development and prevention of diabetes will need to be identified for each specific group of interest and customized as was done with the Latin America Finnish Diabetes Risk Score (LA-FINDRISC) for different Hispanics/Latinos populations[12, 13].

**Table 3. Risk factors for developing type 1 or 2 diabetes[3].**

| Type 1 diabetes | Type 2 diabetes | Prediabetes |
|---|---|---|
| Family history | Obesity or overweight | Obesity or overweight |
| Genetics | Poor diet* | Poor diet* |
| Infection | Physical inactivity | Physical inactivity |
| | Increased age | Increased age |
| | Family history of diabetes, heart disease or stroke | Family history of diabetes, heart disease or stroke |

*Poor diet can include low intakes of fruits, vegetables, whole grains, and fibre, and excessive intakes of calories, saturated fats, and empty calorie foods and beverages.

**Figure 2. Symptoms of Diabetes. Some symptoms are unique to each type and some are similar.**




## Complications

High blood glucose, if not managed, can cause damage to many body organs leading to complications that can decrease quality of life and can even be life threatening. The risk of heart attacks and stroke are two- to three-fold higher in adults with unmanaged diabetes[2]. Observational studies have also demonstrated an association of prediabetes with early kidney disease, nerve damage, vision problems, and vascular disease[14]. Hence, there is an urgent global need to screen, diagnose, educate, and care for people with prediabetes and diabetes, as early diagnosis and management reduces the risk of costly complications.

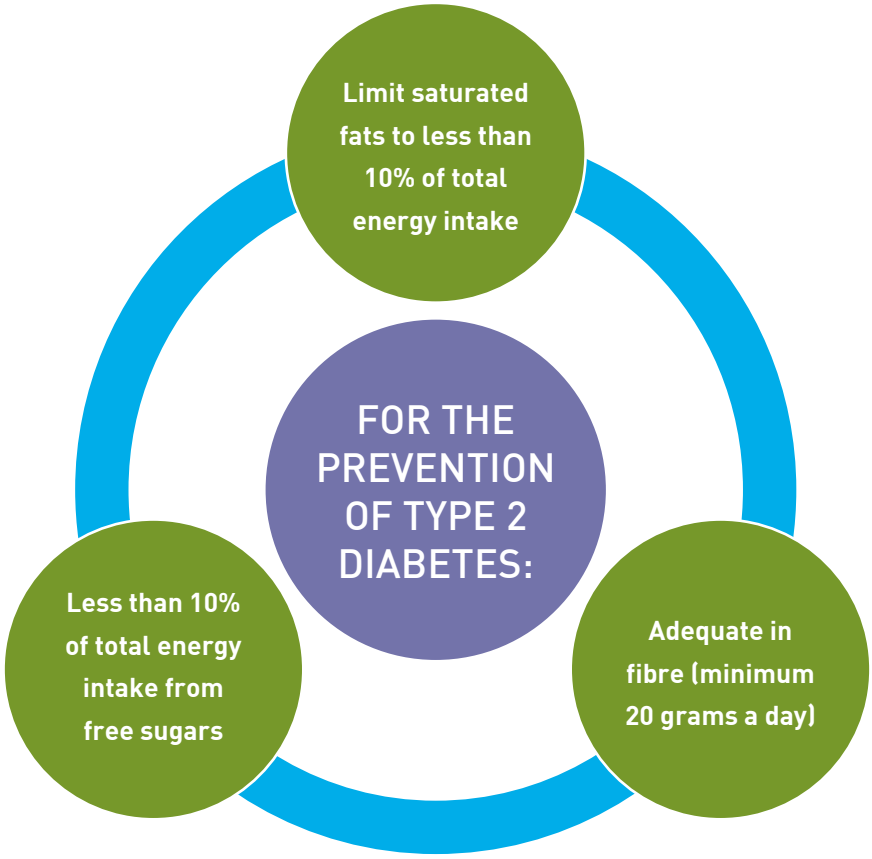
## Prevention

There are no known effective ways to prevent type 1 diabetes and therefore prevention of diabetes in this document is referring to the modifiable factors that have been identified for pre- and type 2 diabetes (i.e. risk reduction). The IDF states that the most influential modifiable factors are the behaviours commonly associated with living in an urban setting and living a modern lifestyle which includes consumption of unhealthy foods, and sedentary, inactive lifestyles. There is strong evidence from randomized controlled trials around the world that simple lifestyle measures such as weight reduction, a healthy diet, and regular physical activity can prevent or delay the onset of type 2 diabetes[15].

## Diet for Reduced Risk and Management of Diabetes

For the prevention of type 2 diabetes, WHO suggests a diet which limits saturated fats to less than 10% of total energy intake, is adequate in fibre (minimum 20 grams a day), and is less than 10% of total energy intake from free sugars, Figure 3[16]. The WHO and IDF also recommend a diet of less than 5% of total energy intake from free sugars for those at risk of diabetes[17,18]. The overall goal of dietary intervention is to manage blood glucose to healthy levels in type 1, pre-, and type 2 diabetes. Dietary guidelines also often recommend a low caloric diet for overweight or obese people with type 2 diabetes to achieve significant weight loss (i.e., 10 kg minimum)[19]. Weight loss should be the primary management strategy because weight loss can reverse some of the metabolic issues observed with type 2 diabetes. Excess intakes of calories, from any combination of macronutrients in food or beverage sources, has a direct association with weight gain[20]. Leading health organizations acknowledge the value of low calorie and non-nutritive sweeteners in reducing calories as part of an overall healthy diet and physical activity regimen. A review paper on the impact of dietary management for diabetes concluded that consumption of non-nutritive sweeteners do not increase blood glucose or the glycaemic response and can be consumed by those with diabetes[21].

**Figure 3. WHO recommendations for the prevention of type 2 diabetes[16].**



# HOW CAN TATE & LYLE PROVIDE INGREDIENT SOLUTIONS?

## Factors that Affect the Blood Glucose Response

A systematic review conducted by the International Life Sciences Institute (ILSI) Europe reported that dietary components can modulate blood glucose levels[22]. While post-meal blood glucose is largely dependent on meal composition, fasting blood levels are only minimally influenced by the amount and/or rate of glucose absorption during the previous meal, and reflect the rate of glucose production in the liver[23]. One of the strongest influences on post-meal blood glucose is the amount and quality of carbohydrates in the diet[23]. Dietary factors that delay the process of digestion and/or absorption of carbohydrates are important in reducing the glycaemic response[23]. Fibres have the greatest impact on the postprandial glucose and insulin response. Foods high in soluble fibre from oats, fruits, and legumes and specific dietary fibres such as beta-glucan, pectin, psyllium, polydextrose and soluble corn fibre have been shown to lower the rise in blood glucose levels after a meal in both healthy individuals and those with diabetes. In contrast, easily digestible and/or refined carbohydrates such as glucose, white bread, short-grain white rice and cooked potatoes produce a rapid rise in blood glucose, followed by a rapid fall.

While diets containing 44 to 50 g of fibre a day are reported to improve blood glucose control in diabetes, this is not a usual level of fibre intake globally and it is recommended that people with diabetes eat 25 to 30 g fibre per day[21].

**NNS use was reviewed in an Academy of Nutrition and Dietetics position paper[24] and states that "consumers can safely enjoy a range of nutritive and NNS when consumed within an eating plan that is guided by current nutrition recommendations as well as individual health goals and personal preferences."**

While added fibres and non-nutritive sweeteners may help with reducing blood glucose response, there are other factors which affect the glycaemic response of a food, including processing, food form, cooking method, ripeness, variety, dietary fibre and overall macronutrient content[23]. Choosing non-nutritive sweeteners can also be helpful in moderating carbohydrate intake, which is important for blood glucose response.

## Tate & Lyle Fibres and Non-Nutritive Sweeteners as Part of the Solution

Tate & Lyle has a portfolio of ingredients that can be used to formulate food and beverage products to reduce calories, sugar, and glycaemic response:

- **FIBRES:** that are clinically proven to lower the glycaemic response when used to replace digestible carbohydrates
- **NON-NUTRITIVE SWEETENERS:** provide very low or no calories and limited impact on blood glucose.

# FIBRES

## Soluble Fibre

PROMITOR® has exceptional digestive tolerance, is stable to heat, pH, and processing stresses.

**PROMITOR® Soluble Fibre 70 provides a minimum of 70% dietary fibre and contains less than 10% sugar. PROMITOR® Soluble Fibre 85 and 90 provide 85% or 90% dietary fibre, respectively, and contain less than 2% sugar. Because they are primarily sources of non-digestible dietary fibre, all PROMITOR® products provide significantly fewer calories compared to fully digestible carbohydrates[ii].**

Two clinical studies and one animal study have evaluated the glycaemic effects of soluble corn fibre (SCF). Kendall et al. showed that the postprandial blood glucose and insulin response to PROMITOR® Soluble Fibre in a lemonade based beverage was significantly lower than a lemonade control containing glucose in healthy subjects[25]. Konings et al. also observed a significant lowering of postprandial blood glucose and insulin levels when 30% of available carbohydrates were replaced with PROMITOR® in foods and a beverage compared to similar full-calorie meals in sample of overweight men and women[28]. Finally, a series of PROMITOR® Soluble Fibre formulations investigated in a study in dogs, were found to significantly lower postprandial blood glucose and insulin responses versus a maltodextrin control.

## Polydextrose

Tate & Lyle's STA-LITE® Polydextrose is a soluble fibre ideal for sugar replacement and calorie reduction. STA-LITE® replaces bulk and mouth feel, and has only 1 kcal per gram[iii]. In 2011 based on available data, EFSA concluded that a cause and effect relationship was established between the consumption of foods/drinks containing polydextrose instead of sugar and reduction in postprandial blood glucose responses (without disproportionally increasing postprandial insulinemic responses) as compared to sugar-containing foods/drinks[27]. The consumption of polydextrose incorporated into foods or beverages have demonstrated a lowering of the glycaemic response.

Jie et al. reported the ingestion of 12 g of polydextrose with 50 g of glucose, significantly lowered the glycaemic response compared to a glucose control in healthy adults[28]. Kurotobi et al. compared the glycaemic index of five strawberry jams made with sugar, corn syrup and sugar, sugar and glucose, apple juice and 40% polydextrose in healthy adults[29]. The glycaemic index for the polydextrose jam was 17 compared to a range of 47-70 for the other jams and 100 for 100% glucose. Konings et al. demonstrated a significantly lower postprandial blood glucose and insulin response following the intake of 57 g of STA-LITE® Polydextrose split between two meals compared to similar full-calorie meals[30].

[ii] Calorie values for labeling may vary according to specific country regulations.
[iii] Caloric values reflect US labeling only. Calorie values for labeling may vary according to specific country regulations.

# RARE SUGARS, NON-NUTRITIVE AND HIGH POTENCY SWEETENERS

## Allulose[iv]

Allulose is a rare sugar that exists at low levels in certain fruits and foods including figs, raisins, molasses, and maple syrup. Allulose is an epimer of fructose without all the calories.

> **Tate & Lyle DOLCIA PRIMA® Allulose is 70 percent as sweet as sugar and can replace sucrose or high-fructose corn syrup and blends well with other sweeteners to reduce calories while providing great sweet taste, mouthfeel, and bulk.**

Allulose is absorbed, but not metabolized, thus has negligible calories[31]. Allulose consumed alone does not raise blood glucose or insulin in normal glycaemic, healthy individuals nor in individuals with type 2 diabetes (unpublished internal reports). Allulose when consumed with glycaemic carbohydrates modestly reduces postprandial glycaemic response in individuals with type 2 diabetes, with prediabetes, and with normal glycaemia[32, 33, 34]. While these results are interesting, further research is needed to determine if there are long-term benefits of allulose in the diet for blood glucose management.

## Sucralose[v]

SPLENDA® Sucralose is heat stable in cooking and baking and works well in a broad range of food and beverage systems. Foods and beverages formulated with sucralose elicit a lower blood glucose response than similar products with sugar.

[iv] DOLCIA PRIMA® Allulose is available in two regions: North America and Latin America

[v] SPLENDA® and the SPLENDA® logo are trademarks of Heartland Consumer Products, LLC.

## Stevia

Stevia sweeteners are extracted from the stevia plant, are zero calories and are considered to have 200 to 300 times the sweetness of sucrose. Clinical studies have evaluated the postprandial glycaemic effect of stevia products in healthy individuals and people with type 2 diabetes, with some indicating no significant change[36, 37, 38, 39] with others indicating a significant reduction compared to a control (placebo, sucrose, water, mixed meal)[40, 41]. One study examined the effect of a beverage containing rebaudioside A from the stevia plant and observed no increases on postprandial blood glucose and insulin levels[36]. A meta-analysis of available randomized clinical trials reported a very small, clinically insignificant reduction in fasting blood glucose when stevia is consumed[42].

## Monk fruit

**Monk fruit extract is a natural, zero-calorie sweetener obtained from monk fruit grown in the sub-tropical climate of Asian hillsides.**

In a study comparing the effects of consuming monk fruit in a beverage, it was found that there were not increases in total daily energy intake, blood glucose or insulin[43]. Tate & Lyle PUREFRUIT™ Monk Fruit Extract is 100-200 times the sweetness of sugar, allowing for sugar reduction up to 100% in certain foods and beverages. This ingredient is appropriate for a wide-range of applications in foods and beverages.

# CONCLUSIONS:

Diet is a modifiable factor for the management of both type 1 and 2 diabetes and to help reduce risk of prediabetes and type 2 diabetes. There are ingredient tools, such as fibres and sweeteners, available to product developers to design foods and beverages with glycaemic response in mind. There are global health and nutrition organizations which recognize the important role these ingredients play in the enjoyment, taste, and health of foods and beverages.

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