Design Requirements for Bread of Low Glycemic Index: Germinated Lentil Use

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Abstract: *Diets based on bread with a low glycemic index (GI) are important for sustainability and for the prevention and control of diabetes 2 mellitus. The aim is to apply the QFD methodology to the design of a new type of bread with low postprandial response for the diabetic population. The postprandial response was evaluated and the GI of bread made with sprouted lentils (two and five days sprouted) was calculated. Forty-seven bread design requirements were identified, including that the bread should be nutritious, without added chemicals, with low GI, and low cost. Using the QFD method, it was suggested that bread made from sprouted lentils with chia could be an option. The GI of this type of bread was found to be low (40, 10). The GI of the bread decreased when lentils with more days of germination were used in its preparation.*

Keywords: Glycemic index, low glycemic index, low glucose response, design of Bread, QFD.

1 Introduction

Bread, a staple food in many parts of the world, generally made from wheat flour (gluten and low in fiber), salt, water, and yeast, has a high glycemic index (GI_H). The glycemic index (GI) is one of the characteristics that indicate the nutritional quality of foods [1]. Consumption of foods with a high or moderate GI is associated with an increased prevalence of diabetes, cardiovascular disease, and obesity [2]. Therefore, a diet with low GI foods (less than 55) is recommended to prevent these chronic diseases. Bread, with an average global consumption of 18 kg/year per person, is one of the world's staple foods and one of the most desired by people. The bread when changes its ingredients in its basic recipes to modify the glycemic index, by changing the type of flour and the use of sugar substitutes with which it is made, it also changes people's sensory preferences and their purchasing power. Thus, despite the popularity of new types of bread in the face of increasing numbers of people with chronic diseases associated with metabolic syndrome, commercial breads are under-consumed, and people continue to consume bread based on recipes that result in GI_H products due to their flour and added sugars.

To avoid the use of wheat flour with gluten (GI_H) and to improve the nutritional benefits of breads, several starches and flour types with the addition of functional ingredients and/or technological approaches that retrograde starch have been proposed [3]. However, the problem of the high GI of bread on the market, together with the price and lack of sensory acceptability of breads with a low postprandial response (low carbohydrate content), is still prevalent in many countries that have a serious problem of increasing cases of diabetes. It is estimated that 422 million people worldwide suffer from diabetes, although there are many people who are still unaware because they do not have the culture of self-monitoring their blood glucose or going for regular check-ups and are not aware of it [4]. Thus, diabetes, one of the chronic diseases that affect a family's quality of life, has become a threat to human health worldwide.

Bread is a major contributor to the daily starch intake in the Western diet. Starch is one of the major digestible dietary carbohydrates contributing to the rise in blood glucose after ingestion. It is necessary to develop bread with a low glycemic index (GI_L). However, it is important to address the needs of the population to improve the consumption of bread with a GI_L, especially for the low-income population who would not be able to afford the current type of bread available on the market. A relevant factor in the prevention of diabetes is therefore a diet with a low glycemic response (GR_L) or low postprandial response (PR_L). It is then necessary to develop food products that reduce this response, based on the needs of the customer, in this case the consumer who chooses a healthy and preventive lifestyle, the already insulin resistant and the diabetic.

Sensory preferences of the consumer are changed by the addition of bread that fulfills this purpose. In the case of packaged bread. It has been reported that when a bioactive element, fiber, protein, etc. is added, sensory preferences are modified and so is the price. The price average of the bread fortified or bread without wheat flour that is commercialized at Mexico City is of 1.84 usd/100g compared to the traditional white loaf of 0.34 usd/100g. It would be of interest when designing a food product with PR_L to start with the context, start with who needs it and their requirements for designing a new food product, in this case a low glycemic index bread, as stated in transdisciplinary research according to the authors who promoted mode 2 to generate knowledge to start the research in the context of the application [5] to generate GI_L or PR_L breads that meet the requirements of the majority of the population. Few studies have been found in the literature that consider bread design according to the requirements of the consuming population prior to formulation and targeting different pathologies. The aim of the research is to apply the QFD methodology to the design of a new type of bread with low postprandial response or GR_L based on the requirements of the target population: subjects with diabetes mellitus type 2. The research will also be complemented by the design and evaluation of the postprandial response and GI of boxed bread made from sprouted lentils (two and five days of sprouting) added with chia seeds.

1.1 History of the Research

Epidemiologic studies have shown that as nations become more affluent, the nature of the population's carbohydrate intake changes so that the ratio of complex carbohydrates (starches) to simple carbohydrates decreases [6]. Depending on the carbohydrates and sugars contained in the food, there is a glycemic response. Foods are therefore characterized by a parameter known as the glycemic index, which depends on the characteristics of the carbohydrates and sugars in the food and consequently on the increase in glucose produced after consumption. Simple carbohydrates are more readily available and can raise blood sugar levels more quickly. Studies showing this date back to the last century.

The similar effect of glucose and starch was discovered at the beginning of the last century. Wishnofsky and Kane estimated blood glucose levels after ingesting 100 g of glucose and 90 g of starch in diabetic patients. The researchers found that there was no significant difference in the degree of increase in blood glucose caused by the ingestion of glucose or its starch equivalent. The sugar excreted in the urine was almost the same in both tests [7].

In 1936, Jerome W. Conn and L. H. Newburgh of the University of Michigan demonstrated that it is important for a diabetic to obtain a large proportion of his total metabolic glucose from protein foods [8], as these keep the glycemic response flat. The researchers administered breakfast consisting of 2 g/kg of protein. The protein was lean ground beef cooked as a hamburger with all visible fat removed (5-6% fat and 20-22% protein). Blood and urine samples were collected for eight hours to measure glucose. On another day, a breakfast consisting of 1 g/body weight of carbohydrate was administered. This meal was given as glucose or as a carbohydrate meal calculated to produce this amount of glucose. If the carbohydrate was used, samples were taken over three to four hours. In several subjects, the researchers compared the response to different carbohydrate foods that produced equivalent amounts of glucose and compared it to the response when the glucose came from protein. Protein was assumed to produce glucose equivalent to 50% of its weight during metabolism.

The results found at this time indicate that, as expected, glucose ingestion increases blood and urine glucose in the subjects tested. In the case of the result found for the consumption of equivalent glucose from protein, the finding of interest is that the glucose response curve obtained remained flat at equivalent amounts consumed of glucose obtained from protein, these results were in diabetic subjects. The curves after protein ingestion remain flat for a period of 8 h. In the researchers' report, they point out that there was marked glycosuria (presence of glucose in the urine) after the ingestion of glucose or carbohydrate, whereas there was none after the protein meal.

Lenner studied the glucose and glycosuria effects of eating different breakfasts with different carbohydrate (CHO) and carbohydrate and oligosaccharide contents. The two breakfasts with the highest oligosaccharide content were associated with a lower increase in blood glucose in adult subjects. These breakfasts cause clear symptoms of hypoglycemia in both adults and adolescents. In adolescents, the initial blood glucose level was found to be more important for the test result than the type of carbohydrate consumed. Breakfasts high in CHO caused significantly higher increases in blood glucose than meals low in CHO. However, the findings suggest that diabetic breakfasts rich in oligosaccharides caused less of a rise in glucose than meals dominated by wheat starch (as in the continental breakfast). Authors noted that the use of oligosaccharide-rich diets should be avoided because of the risk of hypoglycaemic symptoms [9].

The glycemic response to carbohydrate-rich foods has been studied over time. For example, the postprandial and insulin responses of 14 men and two women to intakes of 50 g of carbohydrate from various foods were studied. It was reported that dextrose (44 mg/100 ml), potatoes (49 mg/100 ml), and corn (38 mg/100 ml) were the foods that increased blood glucose levels more than bread (29 mg/100 ml) and rice (27 mg/100 ml). All reached their maximum rise within half an hour of consumption, except potato, which peaked at 45 minutes. However, plasma insulin levels were highest for destrosa (84 mU/mL), potato (64 mU/mL), and bread (57 mU/mL). It should be noted that these results were based on the specific characteristics of the foods at that time. Today, studies have shown that white bread is one of the foods that raise glucose levels the most after ingestion [6].

The effect of foods on blood glucose levels became increasingly important and interesting to the scientific community. At the University of Toronto, David J.A. Jenkins (1981) related the glycemic response produced by food to that produced by glucose and introduced the concept of the GI of foods. Foods are classified by the FAO as low (≤ 55), medium (56-69) and high (70 ≤) according to their GI [10]. GI is a measure of the potential of carbohydrates to raise blood glucose [11, 12]. Jenkins et al. proposed the first table of foods classified according to their GI [13].

The authors studied the blood glucose levels of subjects given 62 commonly consumed foods and sugars individually in groups of 5 to 10 healthy fasting volunteers. Blood glucose levels were measured over 2 hours and expressed as a percentage of the area under the glucose response curve when the same amount of carbohydrate was consumed as glucose. One of the important results of this study was the determination of the GI of some foods. The foods with the highest GI were cereals and cereal products such as whole wheat bread (72) and white bread (69), cornflakes (80), wheat cookies (75), millet (71); and some vegetables such as parsnips (97), carrots (95), instant potatoes (80), new potatoes (70), swedes (72), broad beans (79).

The largest increases were seen in parsnips, carrots, and potatoes, followed by breakfast cereals and cookies. Among fruits, bananas and sultanas had the highest GI. Dairy products (35 ± 1%) and dried legumes (31 ± 3%) had lower GIs; lentils had a GI of 29%. Among other foods, energy drinks (95) and honey (87) had the highest GIs. Of the total foods evaluated by the researchers, the foods with the lowest GIs were peanuts (13), soybeans (15), and canned beans (14). One of the tasks of the scientific community has therefore been to determine the glycemic index of foods to be able to make recommendations to diabetics, pre-diabetics, and the general population as to which foods they can consume in order to take care of the glycemic response. Low GI foods have a lower postprandial response.

Consumption of foods with a low glycemic index is recommended, as foods with a high glycemic index and/or postprandial glycemic response have been associated with an increased risk of developing type 2 diabetes. In addition, elevated postprandial insulin (Produced by high GI foods) may play a role in the development of obesity and insulin resistance, cardiovascular disease, retinopathy, nephropathy and neuropathy, among others [14, 15].

Consumption of foods with a GI_L has been recommended for disease prevention. In this sense, peanut snacks have been recommended. Other snacks have also been suggested for their low glycemic response, such as almonds. Brown et al. investigated the glycemic effects of mid-morning consumption of sweet cookies and almonds. The results reported by the authors indicate that the glucose response to the consumption of sweet cookies begins to increase at 15 minutes, with the maximum glycemic response occurring at 30 min. However, when almonds are consumed, the glycemic response does not increase and the response curve remains flat when plotted over time; in fact, the glucose level tends to decrease after 30 minutes. For this reason, almond snacks are recommended because they are beneficial to those who consume them [16].

Therefore, the suggestion of foods with a lower postprandial response and therefore a GI_L is gaining interest in the scientific community. Moderation of the response of high-carbohydrate foods has been reported by several authors, especially for foods that are widely consumed worldwide, such as bread. Bread has been reported in different pathologies, including diabetic, insulin resistant or even young or healthy adults.

Bread with hazelnut added in 30 g and 15 g portions significantly reduced the area under the blood glucose curve ($P < 0.001$) 45 min after consumption compared to control bread [17]. Other studies suggest a decrease in the area under the curve of total insulin required for a given glucose response of breads supplemented with baobab fruit extracts and a tendency for glucose levels to decrease 30 min after bread consumption [18]. The GI of white bread was significantly reduced by the addition of 3000 mg of white kidney bean (*Phaseolus vulgaris*) extract powder, taking advantage of its ability to inhibit alpha-amylase, which is responsible for breaking down starch into sugars that are absorbed in the small intestine.

New proposals are being developed to reduce the glycemic response or GI of bread by adding proteins, fiber and different fats. Other proposals can be found in the literature, such as wheat bread to which vegetables (pumpkin powder) and flaxseed have been added, showing a tendency to reduce the glucose and insulin response. The carbohydrate measurements (g/100 g) of bread were reduced (27%) in the fortified bread (33.9 g) compared to the processed white bread (46.7 g). Soluble and insoluble fiber and beta-carotene were also increased. In the satiety perception test, all 9 participants reported that they were satisfied and could eat it adequately, and the data were comparable with white bread [19]. Other studies assessing the acceptability of vegetable bread in adults suggest that the swallowing and liking of vegetable-enriched bread is comparable to that of commercial bread. However, it is important to note that acceptance of the proposed fortified bread is not always achieved in the population due to taste, color, or cost, among other factors [20].

Other vegetables have been used as additives in bread making, such as bread made with different flours (corn (330 g), rice (300 g), potato (300 g)) with the addition of vegetables such as broccoli, cauliflower, artichoke, fennel and zucchini at 15% of the total 930 g of flour. The GI of the vegetable breads was lower compared to the control bread (100) (no vegetables added). The bread type with the lowest GI was artichoke (65), followed by zucchini and broccoli bread (70) and cauliflower (75). There was also an improvement in the functional properties by increasing the concentration of flavonoids, total phenolics and antioxidant capacity of the breads with vegetables. It should be noted that the bread with the best sensory score was the fennel bread; the lower GI breads were reported to have improved sensory properties. It is important to note that even plant residues could potentially be useful for the production of functional bread [21]. Using organic residues, bread has been reported with the addition of onion, coriander (Coriandrum sativum), purple cabbage (*Brassica oleracea* var. capitata), parsley (*Petroselinum crispum*), black radish (*Raphanus Sativus*) peels, tomato peels (*Lycopersicum esculentum* Mill.) and coffee (*Coffea arabica* L.) grains have been reported [22, 23].

Psyllium husk powder has been reported to be used to make gluten-free bread. It was added to bread to improve fiber content and glycemic response, as well as texture. The glycemic response and GI of wheat bread, gluten-free bread, and gluten-free bread with 17.4% *psyllium* added were compared. The glycemic response of wheat bread and gluten-free bread (rice, manioc starch, whole egg, whole milk powder, sugar, soybean oil, and yeast) was similar. However, the glycemic response of the gluten-free bread with *psyllium* was reduced by 33% compared to the other breads, resulting in a GI_L bread (G=50). In addition to improving the volume, appearance, texture, acceptability, and fiber content of gluten-free breads [24].

The use of sourdough has also been studied to reduce glycemic response. Researchers have reported on the glycemic response of bread consumption to a change in yeast type. Only the yeast used to make the bread was changed in the same dough. The dough, with the same characteristics, was divided into two exact halves, with two different types of leavening agents used for each half: (1) commercial baker's yeast consisting mainly of *Saccharomyces cerevisiae*; (2) a natural sourdough starter consisting of a mixture of yeasts and bacteria (*Saccharomyces cerevisiae, Lactobacillus brevis SB3, and Lactobacillus plantarum*). The subjects were given 10 g of butter, 15 g of jam, and 100 g of bread. The results found by the authors indicate a maximum glucose peak at 30 minutes for both breads made with commercial yeast (143 mg/dL) and natural sourdough yeast starter (133 mg/dL), starting from an initial glucose level of 110 mg/dL. Glucose levels tended to be lower when participants consumed bread made with sourdough yeast starter [25].

Bioactive compounds have also been added to bread to reduce the glycemic response; white bread with turmeric was found to reduce the glycemic index by 7%. Curcumin from turmeric is thought to have inhibitory effects on α-amylase activity, thereby reducing starch digestibility [26].

Polyphenols from marine algae (*Ascophyllum nodosum* and *Fucus vesiculosus*) were added to bread at 0.5 and 2% to study the effect on glycemia after consumption of 100 g of available carbohydrate and carbohydrate digestion. At these levels of addition to bread, the effects of glucose tended to decrease, but without a significant difference. However, algae added to the control bread in vitro significantly reduced the level of carbohydrate digestion compared to the control bread. The authors reported that the effect of the seaweed is likely to be reduced in the baking process [27].

Edible seaweeds (*Wakame, Undaria pinnatifida and Chondrus, Chondrus crispus*) were added to modify the starch digestibility index and GI of white bread. The algae reduced the digestibility of white bread, showing an ability to modify starch digestibility in vitro. The glycemic index estimated from the degree of starch hydrolysis in 90 min was low (79) with respect to the white bread used in this study (value 100) [28].

Some ingredients are not readily accepted, such as bread fortified with seaweed (Ascophyllum nodosum) added at 0% (control), 1%, 2%, 3%, and 4%. Consumption of the fortified bread at breakfast resulted in a significant reduction in energy intake (16.4%), but the authors report no significant statistical differences in glycemia. It is interesting to note how the subjects sensory preferences decreased with the fortified bread, mainly in terms of taste, texture and overall acceptability of the bread. Some other studies have reported acceptable formulations at 2.5 or 3% ingredient addition to bread. In this study, the authors report 2%. In this case, perhaps one aspect to consider, as other authors have pointed out, is that the baking process degrades the constituents that make up the seaweed and have therapeutic effects, although it could also be argued that the effects on glucose could occur by increasing the percentage of seaweed in the bread [29].

Other bakery products [30] were supplemented with 2.5, 5 and 7.5% spirulina (*Sp*) powder, showing a highly significant difference between wheat flour cake (control) and supplemented cake for all sensory attributes and overall acceptability. The lowest score was recorded for the cake supplemented with 7.5% (Sp). The cake supplemented with 2.5% (*Sp*) had the highest score for all sensory attributes studied. Spirulina is a cyanobacterium that lacks a rigid cell wall, which results in higher water absorption rates (due to its cellular components, mainly protein structure). In fact, Spirulina's hydrophilic protein molecules compete with starch molecules for water binding sites, destabilizing and delaying starch gelation, resulting in a more fragile gel structure. However, it has the advantage of having a wide range of macro- and micronutrients and has also been used in several studies to lower blood glucose due to its therapeutic properties, making it one of the most complete functional foods [31, 32]. Spirulina added to foods tends to lower their GI. Other functional foods also lower the GI when added to baked goods.

Chia is another functional food that has been added to white bread. It was reported that bread with 5% and 10% chia added to their formulation had more protein than the control bread. They also showed a lower hydrolysis index, from which they calculated the glycemic index of the bread, with the chia bread also having a lower glycemic index than regular bread. Chia bread reduced the glycemic index (75) by 25 points compared to white bread (100) when 10% whole grain chia flour was added. The authors point to chia as an ingredient that could help prevent metabolic disease. The beneficial effects on glucose metabolism, together with the nutritional and functional properties, may be clinically important for the prevention of metabolic diseases [33].

It is important to note, chia is one of the ingredients that has been studied for its potential to be accepted by consumers. Zhu and Chan [34] studied the overall acceptability of Chinese steamed bread with chia added and obtained similar scores to the control bread. They recommend the addition of up to 300 g/kg of chia seed in bread formulations to enhance its nutritional benefits, without compromising the quality of the food and the consumer's taste for it. The addition of chia seeds reduced GI by up to 48%. In this study, the authors point to the cost of the white chia used, which in New Zealand was around USD 1.4 per 100g [34].

On the other hand, other authors have proposed nutraceutical wheat bread with the addition of lentil sprouts. Hernandez-Aguilar et al. added 0.5 and 10% lentil sprouts. It was found that the content of phenolic acids and flavonoids tended to increase in the bread with sprouts added at a concentration of 10%. In addition, the bread with lentil sprouts had sensory acceptability in its general characteristics in a group of people with diabetes and/or diabetic family members [35]. In populations such as Mexico, it is important to emphasize that lentils are culturally accepted by the population. Little is known about lentil sprouts, but they are one of the easiest sprouts to produce and have at home. The cost of 10 grams of lentils is about USD 0.29, unless it is organic, in which case the price increases to about USD 0.5. In the present research, it is relevant to focus on the needs of the consumer who wants to prevent diabetes, insulin resistance, or diabetic, in order to design bread that can be consumed.

2 Methodology

2.1 Methodology QFD

The Quality Function Deployment (QFD) methodology is a tool used to translate customer needs and requirements into design features and specifications of a product or service. This methodology was developed by Yoji Akao in the 1960s and introduced to the USA by Masao Kogure and Yoji Akao. The steps of the methodology can be stated as follows [36-38] 1) Identify customer needs. - The first step is to identify the customer's needs by collecting information about the customer's needs and then classifying them. 2) Suggestion that can satisfy the customer's needs. 3) In this step, the relationship matrix is created. "The relationship matrix is the lifeblood and focal point of the QFD methodology. It shows how the functions of the product or service meet the customer's needs. 4) Assign weights to the customer's needs. The weights assigned to customer needs reflect their relative importance. 5) Calculate priority scores. Priority values indicate the importance of each feature of the product or service in satisfying customer needs. Multiply the weight of each customer need by the corresponding ratio value. Add the resulting values to obtain the priority score. 6) Graphically display the QFD diagram. The QFD diagram is a visual tool that helps to communicate information about customer needs and product or service functions. The competition is considered and how it meets the customer's needs. A synthesized summary of the QFD methodology is shown in Figure 1.

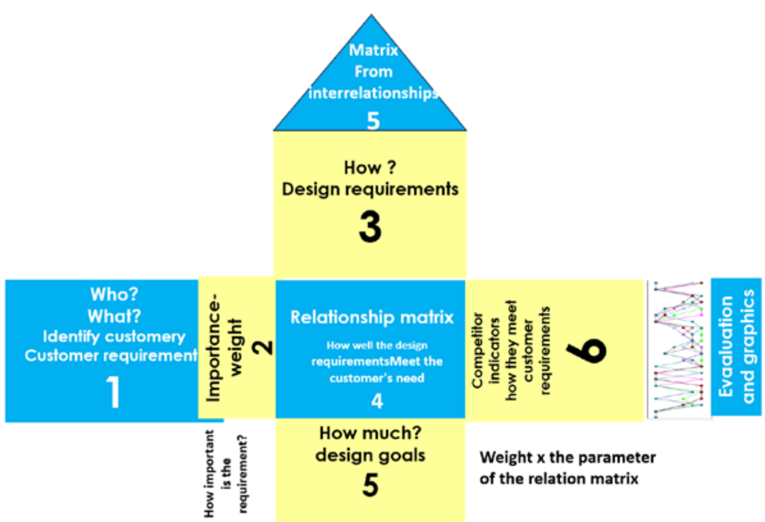


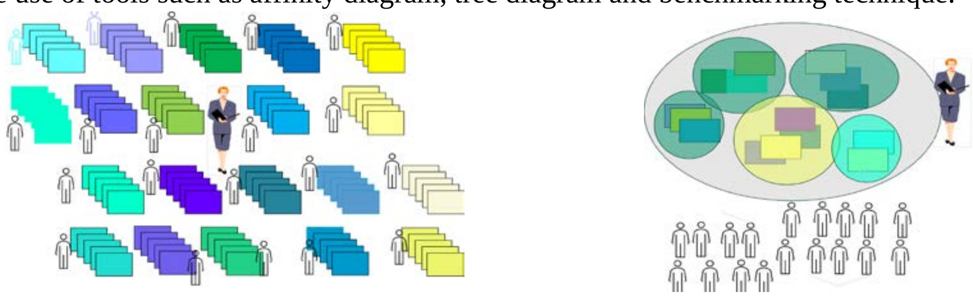
Figure 1: Synthesized steps of the QFD Methodology (Quality Function Deployment) based in [37].

2.1.1 Participant Subjects

There were 25 participants, including normal (13, 9 male and 4 female), diabetic (6, 2 male and 4 female) and insulin resistant (6, 3 male and 3 female) subjects. Age ranged from 30 to 55 years.

2.1.2 Requirement of Box Bread

Once the group of participants was selected. An adaptation of the TKJ technique [39, 40] was used. This consisted of each participant writing their idea of the requirement on a card or sheet of paper. In this case the question was what are the requirements for a new design of bread for diabetics? The research method includes the use of tools such as affinity diagram, tree diagram and benchmarking technique.



(a) (b)

Figure 2: TKJ technique, some steps where it is illustrated a) pose the question and write on cards or sheets and b) classify the requirements by affinity diagram adapted from [39, 40].

2.1.3 Prioritization of Bread Box Requirements

Once the requirements for a new bread design had been established, these requirements were ranked and participants were asked to rate the importance of the requirement on a scale of 1-5, with higher ratings indicating greater preference or importance. The number of participants who gave a score of 5 for each of the requirements was counted. Based on this, the number of participants who rated the requirement as 5 was counted for each requirement. From these data, the value of the relative weights of the requirements for a new design of bread for diabetics was obtained by $Ir = \left(\frac{\Sigma +}{C}\right) 100$ [37].

2.1.4 Market Brands Selling Boxed Bread and Evaluation of Compliance with Requirements

The bread brands on the market that could be consumed by diabetics were identified and rated on a scale of 1-5 based on customer requirements. Five breads for diabetics were identified, which can be seen in Table 1 (ingredients, price online, and specifications in packaging).

Table 1: Commercial bread with lower glycemic response

Type of bread	Commercial Bread	Ingredients	Price online	Packaging specifications
1. Eze (680 g)	Food for Life Frozen Whole Grain Bread 680g	Organic sprouted wheat, water, organic sprouted barley, organic sprouted millet, organic malted barley, organic sprouted lentils, organic sprouted soybeans, organic sprouted spelt, yeast hydrolysate, organic wheat gluten, sea salt. Contains: Soy, gluten (wheat, barley, spelt). May contain tree nuts.	175	Low glycemic index (36) Ingredients Wheat, barley, beans, lentil, Millet, spelta.

2. Oro (567 g)	Superior Keto Bread 567 g	Water, Modified Wheat Starch, Wheat Protein Isolate, Sunflower Flour, Vegetable Oil (Soybean), Yeast, Inulin, Oat Fiber, Sea Salt, Preservatives [Calcium Propionate, Sorbic Acid], Soy Lecithin, Guar Gum, Maltodextrin, Xanthan Gum, Mono- and Diglycerides, Citric Acid, Sesame Seeds	293	Keto Excellent source of fiber Net Carbohydrate per slice (5.2 g) 47 kcal
3. Ho Ke (453 g)	Ho **Wheat Keto** 453 G	Wheat miel	129.99	Keto Friendly 40 calories/slice
4. Ce Ce (680)	CeCe 680 g	Sprouted wheat grain, wheat gluten, yeast, natural flavouring, iodised salt, enzymes, soya lecithin,	100	Sprouted wheat grain bread Protein: 10.2 g * * * Glicemic Index 43 * *
5. Ke bra (650)	Keto Pan	Ingredients: Ground almonds, coconut oil, egg white, aluminium-free royal, xanthan gum, stevia, sea salt, organic apple cider vinegar.	399	Bread made from almond flour Gluten-free and Dairy free

2.1.5 Design Requirements to Satisfy the Client's Needs.

The requirements to satisfy the customer's needs are derived from the calculated priority values. Calculate the values: Multiply the weights of each customer requirement by the corresponding ratio value. Summing the values: The resulting values are added together to obtain the priority value for each function of the product or service. Create the Quality House Map graphic: A template already developed in the QFD methodology is used. In this way, the diagram is interpreted to identify the most important functions to satisfy the customer's needs. From the quality house diagram, the design proposal is established according to the economic importance and functional properties of the new diabetic bread design. In this case, the best evaluated ingredient was sprouted lentils.

2.2 Bread design. Germination of Lentils, Formulation of Bread, Glycemic Response and GI

2.2.1 Germination of Lentils

Germination procedures were adapted from those reported in the scientific literature [35, 41], the lentils were left in water for 24 hours. They were then transferred to a sieve covered with paper (placed over a container to drain water) at room temperature (average 25 degrees). They were rinsed daily and left in the sieve again. Established lentils were used after 1) two days and b) five days of germination. The average size of the seedlings was half a centimeter after one day and between 2.5 and 3 cm after 5 days (the seedlings started to leaf out). The drained and sifted lentils were used to make bread.

2.2.2 Formulation of Germinated Lentils Bread

The germinated lentils breads were enriched with black organic chia (*Salvia Hispanica* L.); two cases were studied: Case I. Two-day germinated lentil bread enriched with chia. Case II. 5-day germinated lentils bread enriched with chia. The ingredients used to make the dough were, in percentages: lentil sprouts (50.12%), chia (12.04%), milk (30.12%), pepper (1%), yeast (1.2%), Himalayan salt (0.4%), olive oil (3%), vinegar (2%); whose macronutrients (Proteins, fat, carbohydrates and fiber) and prices are shown in Table 1. No preservatives or gluten have been added. The ingredients were placed in a blender (Oster) and blended for 4 minutes. They were then placed in a silicone mold measuring 15.5 x 7.5 x 6 cm. The bread was baked (oven Oster) for 45 minutes at a temperature of 180 °C.

2.2.2.1 Bread Color

The color of the different breads was determined using a spectrophotometer (Sensergood, India). The color parameters corresponding to the CIELab uniform color space (L*, a* and b*) were obtained directly from the instrument. L* indicates brightness (100= White and 0=Black), "a", indicates greenish reddish [negative (-a) (green) to red (+a) (positive)] and "b", indicates bluish yellowish [negative (-b) (blue) to yellow (+b) (positive)]. The instrument was calibrated using a reference target. Additional color parameters were determined as whiteness index (BI), yellowness index (YI), tone (h_{ab}) and crome (C_{ab}) [42, 43]. Finally, the color differences in the CIELAB space between the breads were determined ($\Delta E_{BreadG1-Bread\ G2}$) and the browning index (BI) [44].

Table 2: Formulation of lentil bread elaborated.

Bread comercial	Percentage (%)	Description (portion 100 g) (g)	Price usd
Germinated lentils	50.20	Protein: 4.4, fat: 0.6, carbohydrates: 8.6, fiber: 2.7.	0.35
Chia (organic)	12.04	Protein: 17, fat: 31, carbohydrates: 42, fiber: 34.	0.77
Milk	30.12	Protein: 5, fat: 2, carbohydrates: 3.4, fiber: 0.	0.29
Pepper	1	Protein: 0, fat: 0, carbohydrates: 0, fiber: 0.	0.16

Yeast	1.2	Protein: 44 g, fat: 2, carbohydrates: 41, fiber: 26.	0.11
himalayan pink salt	0.4	Protein: 0, fat: 0, carbohydrates: 0, fiber: 0.	0.01
Olive oil	3	Protein: 0, fat: 91, carbohydrates: 0, fiber: 0	0.19
Vinegar	2	Protein: 0, fat: 0, carbohydrates: 0, fiber: 0.	0.004
			1.884 usd

Cal: Calories, CHO: Carbohydrate

2.2.3 Glycemic Response

Ten participants were enrolled in this study. They included 5 diabetic subjects (3 women and 2 men) and 5 healthy subjects (4 women and 1 man). Only one of the healthy subjects was overweight according to the established body mass index ranges (BMI<18.5, underweight; 18.5 <BMI<24.9, normal weight; 25.0 <BMI<29.9, overweight, BMI >30.0; obese) according to [45]. The mean age of the participants was between 36 and 58 years. Of note, all 10 participants had a family history of diabetes

The bread was prepared according to the proposed recipes, in accordance with the established requirements, choosing for its preparation germinated lentils in two germination times. 1) germinated for two days and case 2) germinated for 5 days. After preparation, the bread was left to cool and then rapid glucose tests were performed by finger prick using a capillary glucose meter, Glucometer /Accu-chek instant (model 963, a commercial brand of Roche). Basal (pre-bread) fasting glucose was obtained (after informed consent was signed by the participants). The bread was eaten, and postprandial glucose was measured every 15 minutes (0.25 h) for 2 hours. In this way, postprandial response curves were constructed from the participants' blood glucose data. All participants received the same amount of bread (50 g), which was weighed and bagged for delivery to them.

The research protocol followed the guidelines of the Mexican Official Standard NOM-012-SSA3-2012 [46], which establishes the criteria for conducting human health research projects. In this sense, the participants signed an informed consent form.

2.2.4 Estimation of GI

The estimate of the glycemic index (GI) is obtained through equation 1 [13, 47].

GI = Area under the curve for germinated lentil bread (AUC-BG1) / Area under the curve for pure glucose (AUC-BG2) x 100 (1)

The area referred to for food and pure glucose is that corresponding to the postprandial response. Participants measure their glucose before and after eating bread. These glucose points form a curve. To measure the glycemic index, the area under the curve of the designed food must then be determined. The quotient of the expression in the denominator has the area under the curve of the postprandial response when consuming pure glucose. In this case, the data were taken when consuming 50 g of pure glucose [48].

Area under the curve is calculated by trapezoidal method [49]

$$A \approx (h/2)\,(y_0 + 2y_1 + 2y_2 + \dots + 2y_{n-1} + y_n) \quad (2)$$

A = area under the curve

h = Interval between each point (in this case, 15 min = 0.25 h)

$y_0, y_1, y_2, \dots y_n$ = function values (glucose increase) at each point

2.2.5 Statistical and Principal Component Analysis

Once the data were recorded, they were arranged as needed in the SAS program for statistical analysis. Analysis of variance and comparison of means were performed using the least significant difference test [50]. The software used was SAS (SAS Institute, 2008) [51]. and Origin (version 2017) and the level of probability used was 5% error

3 Results and Discussions

3.1 Methodology QFD

3.1.1 Requirement of Box Bread (normal and insulin-resistant subjects)

According to the TKJ method, by asking the question "Characteristics that you think should be considered for a new bread design", 47 requirements for a new bread design were defined, divided into packaging appearance (7), sensory preferences (9), cost (1), bread availability (1), production process (5) and properties (28). As can be seen from the participating subjects, they have more requirements in the attribute related to properties, followed by compliance with sensory aspects (Table 3).

Table 3: Characteristics that you think should be considered for a new bread design

Packaging appearance (7)	1. A nice looking packaging	Properties (28)	24. Bread added with accessible and natural bioactives (sprouts, curcuma, spirulina, etc.) and vegetables (cauliflower, broccoli, nopal).
	2. A packaging is environmentally friendly		25. Bread added with waste (leftover - peels, organic - parsley stalks, coriander, tomato peels)
	3. Packaging with government nutritional labeling identification.		26. Low glycemic response bread
	4.Wrapper with the identification if the product is for diabetics.		27. Bread shelf life
	5. Wrapper with food traffic lights according to GI or CHO.		28. High fiber bread
	6. Hermetically sealed packaging		29. Bread is fortified with legumes (beans, bean, soybean)
	7. Vacuum sealing of the packaging		30. Bread fortified with animal protein (egg, fish)
Sensorial (9)	8. Change of bread color (nopal, curcuma, spirulina, flaxseed, etc.)		31. Bread without chemical conservatives
	9. Bread size smaller than commercial size		32. A nutritious bread
	10. Bread size larger than commercial		33. Bread without side effects (inflammation, laxative)
	11. Pleasant flavor		34. Low calorie bread
	12. Aroma		35. Bread low in saturated fat
	13. Chewiness		36. Bread made with healthy fats (coconut oil, ghee, olive oil)
	14. Smooth consistency		37. Bread with natural leavening agent: yeast (comercial)
	15. Freshness of bread		38. Bread with chemical bicarbonate leavening agent (baking soda)
	16. Texture of bread		39. Bread with natural conservative (*curcuma*)
Cost	17. Low-cost bread		40. Bread with traditional ingredients: wheat flour

AV	18. Bread available		41. Bread that retains its characteristics over time
Process (5)	19. Quickly baked bread		42. Gluten bread (from wheat)
	20. Using technology to beat		43. Gluten-free bread (from wheat)
	21. Bread made in a homemade way		44. Bread made of sourdough
	22. Bread that can be recycled		45. Bread containing sugar substitute ingredients: monk fruit
	23. Refrigerated bread		46. Bread with gluten substitute: *Physillium,* CHIA or Flaxseed (high-fiber shell)
			47. Bread added with chicharron (animal, soy)
	GI: Glycemic index,		
	CHO: Carbohydrates,		
	AV: Availability		

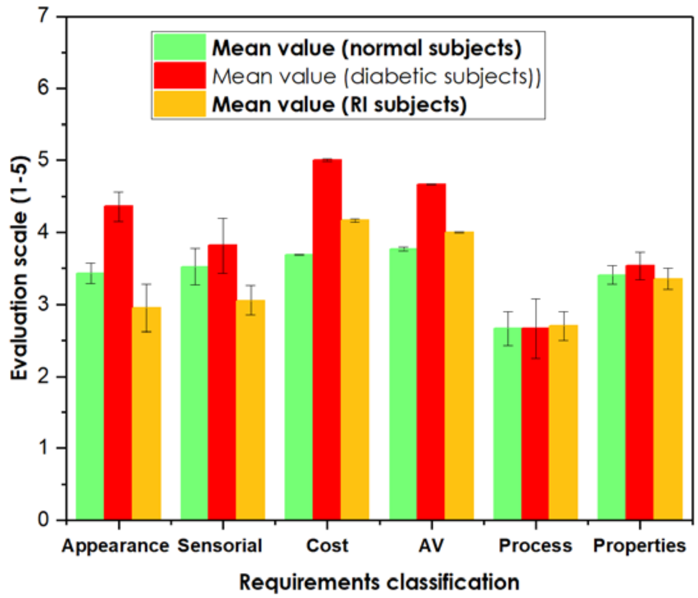


Figure 3: Preferences in bread requirements

Figure 3 shows the preferences for requirements classified as appearance and packaging specifications, sensory aspects to be met by the newly designed bread, cost of the bread, availability to the consumer (AV), production process and preservation of traditional production, and properties according to the ratings of a) normal (healthy) subjects, b) subjects with diabetes, and c) subjects with insulin resistance (RI).

Diabetics have the highest ratings, with statistically significant differences ($p<0.05$), for requirements related to appearance and packaging specifications, cost and availability. Among the relevant aspects according to the diabetic approach, they would like to see a specification indicating that the new bread design is suitable for diabetics, a kind of food traffic light based on the characteristics of the food in relation to its glycemic response. In general, the attribute of greatest interest to diabetics is availability and cost, and the least interest is in requirements related to the bread making process.

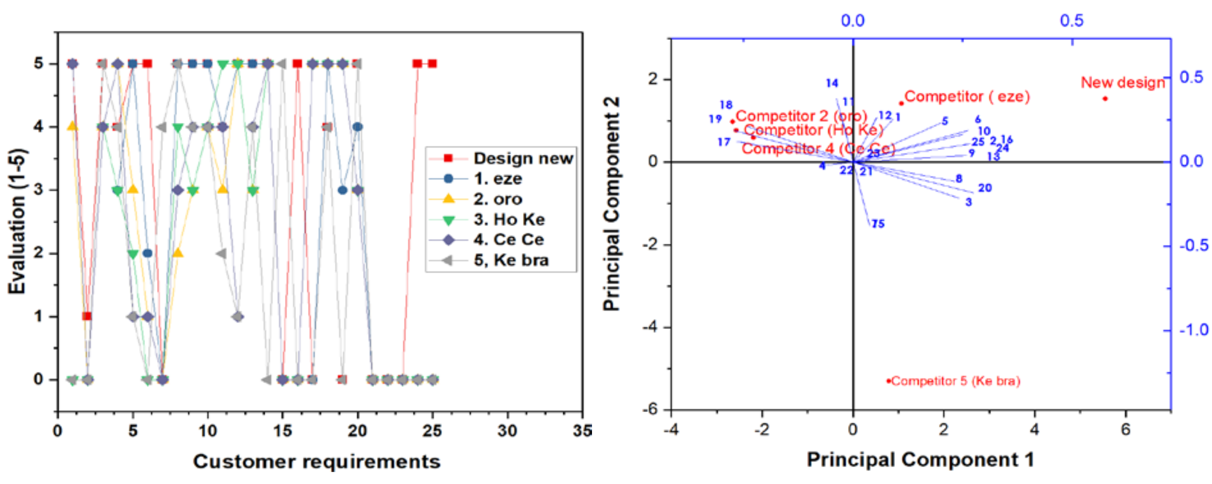
3.1.2 Prioritization of Requirements (diabetic subjects) and Competitors

Table 4 shows the requirements according to the classification of properties (28 options of specific requirements) required in a new bread design and the cost (1 requirement considered). According to the preferences of the group of diabetics who evaluated the requirements related to bread properties and cost, it was found that the specific requirements with the highest relative weight, i.e. what is desirable for the group of diabetics is a nutritious bread (10.9), followed by low calorie bread, no side effects (8.9), low glycemic index (8.9) and low cost (8.9). Lower relative weight scores were found for requirements for breads low in saturated fat (7.1) and made with healthy fats (7.1).

3.1.2.1 Competitors

In Table 4 it is possible to observe the evaluation of 5 low carbohydrate breads commercialized in Mexico City, which in this phase of the QFD methodology are evaluated based on the fulfillment of the requirements of the diabetic group, some of their specifications can be observed in Tables 4 and 5.The main non-compliances of the breads marketed according to the requirements of the diabetic panel were that most of them used chemical preservatives, did not add fibers such as chia, flaxseed or *psyllium*, did not use organic waste and were mostly expensive. The prices of the bread reached values of 2.622 and 3.11 usd /100 g (Table 5).

In Figure 4a and b, the new bread design would improve some of the requirements of the current breads, mainly in terms of nutritional properties, bread enriched with legumes, that it is a non-inflammatory bread, that it has added fiber and that it is of low cost. The breads on the market with the most similar characteristics are the competitor's breads (competitor eze) made from sprouts of different seeds (organic sprouted wheat, organic sprouted barley, organic sprouted lentils, organic sprouted soybeans, organic sprouted spelt and gluten (wheat, barley, spelt)) and almond bread (ground almonds, coconut oil, egg white) (Figure 4b). Competitors 2, 3 and 4 performed because they still contain wheat in their production (Table 4). It was not convenient that the bread was wheat bread for people with diabetes, as it has a high glycemic index.



(a) (b)

Figure 4: Compliance with bread requirements by competitors a) Evaluation of the 25 requirements considered, b) Principal component analysis of different brands of bread

Table 4: Relative weight of customer requirements or WHATS for new design of bread and competitors

		Relative Weight	Weight/importance	Customer requirements or Whats	Competitor 0	1	2	3	4	5
Properties (28)	1	0	0	Bread added with accessible and natural bioactives	5	5	4	0	5	0
	2	0	0	Bread added with waste	1	0	0	0	0	0
	3	8.9	5	Low glycemic response bread	5	4	4	4	4	5
	4	7.1	4	Bread shelf life	4	3	5	3	5	4
	5	5.4	3	High fiber bread	5	5	3	2	1	1
	6	1.8	1	Bread fortified with legumes	5	2	1	0	1	0
	7	0	0	Bread fortified with animal protein	0	0	0	0	0	4
	8	1.8	1	Bread without chemical conservatives	5	5	2	4	3	5
	9	10.7	6	A nutritious bread	5	5	3	3	4	4
	10	8.9	5	Bread without side effects	5	5	4	4	4	4
	11	8.9	5	Low calorie bread	4	4	3	5	4	2
	12	7.1	4	Bread low in saturated fat	5	5	5	5	1	1
	13	7.1	4	Bread made with healthy fats	5	5	3	3	4	4
	14	1.8	1	Bread with natural leavening agent: yeast commercial	5	5	5	5	5	0
	15	5.4	3	Bread with chemical bicarbonate leavening agent	0	0	0	0	0	5
	16	1.8	1	Bread with natural conservative (turmeric)	5	0	0	0	0	0
	17	0	0	Bread with traditional ingredients: wheat flour (that preserves the flavor)	0	0	5	5	5	0
	18	7.1	4	Bread that retains its characteristics over time	4	5	5	5	5	4
	19	1.8	1	Gluten bread (from wheat)	0	3	5	5	5	0
	20	1.8	1	Gluten-free bread (from wheat)	5	4	3	3	3	5
	21	1.8	1	Bread made of sourdough	0	0	0	0	0	0
	22	1.8	1	Bread containing sugar substitute ingredients: monk fruit	0	0	0	0	0	0
	23	0	0	Bread with gluten substitute: *Psyllium*, Chia, Flaxseed (high-fiber shell)	4	0	0	0	0	0
	24	0	0	Bread added with chicharron (animal or soy)	5	0	0	0	0	0
Cost (1)	25	8.9	5	Low-cost bread	5	0	0	0	1	0

0: New design; 1: eze, 2: oro, 3: HoKe, 4: Cece, 5:Kebra

Table 5: Specifications of 5 types of commercial breads as ketogenic and low carb in Mexico City.

Bread comercial	Price/ 100 g (usd)	Cal/ 100g (KCal)	Total fat (g)	saturated fat (g)	Sugar (g)	Fiber (g)	Protein (g)	CHO (g)	sodio (mg)
Eze (680 g)	1.28	209	1	0	0	75	15	35	221
Oro (567 g)	2.622	214.28	5.35	0	0	28.57	14.285	39.285	571.42
Ho Ke (453 g)	1.45	177.77	1.11	0	4.44	13.33	11.11	42.22	311.11
Ce Ce (680)	0.74	205	1	0.2	0.6	9.1	15.4	33.7	298
Ke bra (650)	3.11	220	18	3.9	0	8	12	2	0

Cal: Calories, CHO: Carbohydrate

3.1.2.2 Elements of New Bread Design

Once the requirements of the new bread design are known, its evaluation and the approach to ingredients that meet the requirements, and the competition are known. We have elements to develop the design of the new bread for diabetic groups.

Table 6 shows the design elements (column 1) for the proposal that meets the requirements; maximum relationship value (column 2), importance weight (column 3), relative weight (column 4). The design elements proposed to meet the requirements have the highest relationship, as they have been rated on a scale of 9. The level of importance of meeting this functional element is expressed in column 3 of the table, where the highest value is for the proposal to incorporate lentil sprouts (703.6) to strengthen the nutritional content, fiber, resistant starch and low glycemic index.

Other elements that could work to meet the needs of the customer, in this case the diabetic group, would be chia (482.1), lentil (482.1), flaxseed (492.9) and *psyllium* (475.4). Based on these values, a new bread design incorporating these ingredients can be proposed.

It has been reported that lentil sprouts reduce their saponin content, making them more suitable for consumption by people suffering from legume-induced inflammation. In addition, lentil sprouts increase the content of secondary metabolites such as flavonoids [52, 35], which are recommended in diabetic diets. Authors have reported that in non-diabetics, flavonoid consumption is associated with a lower risk of developing type 2 diabetes [53]. Regarding the sensory acceptability of lentils to consumers, it has been reported that lentils are highly acceptable when foods with added pulses are prepared. Other studies have proposed the preparation of yogurt with lentil sprout additives with better sensory acceptability and structure than yogurt without lentil sprouts, increasing the protein content [54].

On the other hand, the consumption of lentil sprouts has been reported to have beneficial effects on glycemic control in obese and overweight patients with type 2 diabetes [55]. Thus, in some communities sprouted lentils are a highly desired food product among other reasons due to their low glycemic index and high levels of potentially resistant starch [56]. which brings a low glucose response.

Table 6: Elements of Design (Max Relationship value in the column, weight importance, relative weight).

Elements of design	MRV	WI	RW		MRV	WI	RW
1. Use for its anti-inflammatory (Turmeric)	9	464.3	5.2	14. For fermentation and leavening. (Yeast)	9	271.4	3.1
2. Implement a reuse system in the kitchen (Use organic waste)	9	239.3	2.7	15. Leavening agent in cooking. (Bicarbonate)	9	253.6	2.9
3. Gluten-free alternative for recipes. (Almond flour)	9	382.1	4.3	16. Turmeric	9	375	4.2
4. Flavor enhancer and antimicrobial properties. (Garlic)	9	214.3	2.4	17. Wheat flour	9	289.3	3.3
5. Source of fiber and nutrients (Chia)	9	482.1	5.5	18. Ascorbic acid, vinager	9	267.9	3
6. Provider of plant-based protein (Lentils)	9	482.1	5.5	19. For greater nutritional content. (Lentil Germinated)	9	703.6	8
7. Add creaminess and flavor to dishes. (Milk and cheese)	9	310.7	3.5	20. Use artisanal bread. (Sourdough)		332.1	3.8
8. Improve the flavor profile. (Pepper)	9	153.6	1.7	21. Natural sweetener. (*Monk fruit*)	9	285.7	3.2
9. Increase protein and nutritional content. (Spirulina)	9	371.4	4.2	22. Improves texture and adds fiber. (*Physillium*)	9	475.4	5.4
10. Alternative for paleo or gluten-free recipes. (Coconut flour)	9	378.6	4.3	23. Source of protein in recipes. ("Chicharron")	9	257.1	2.9
11. Protein-rich grain. ("Quinoa")	9	314.3	3.6	24. Incorporate as plant-based protein. (soja)	9	325	3.7
12. Use in dressings and cooking. (Olive oil)	9	360.7	4.1	25. Add omega-3 and fiber. (Flaxseed)	9	492.9	5.6
13. Use for preparations that require fats. (Coconut oil)	9	364.3	4.1				

M R V: Max Relationhip value in columna, WI: Weight importance, RW: Relative weight

3.2 Bread of lentil germinated, response glycemic and GI

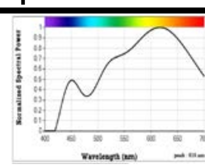
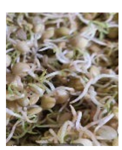
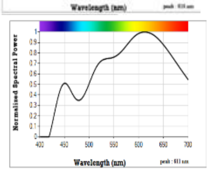
3.2.1 Bread of lentil germinated. Color.

Table 7 shows the color characteristics of the formulation based on lentils germinated at different germination times (2 and 5 days) and chia. The color change of the bread depends on the number of days of germination of the seeds. It is possible to observe different colors of the breads due to the content of pigments present [57].

The L*, a* and b* values of the breads made from lentil sprouts (2 days germination and 5 days germination) had a significant difference ($p < 0.05$) between them. The a* value decreased significantly from 2.7 to 1.8 for bread made from G1 lentils (two days of germination).

In bread, a decrease (33%) in the a* value was observed with an increase in the number of germination days of the lentil. This change could be due to the loss of nutritive compounds during the germination process, which is related to the color of the germinateds, as reported by other authors [35]. The b* values of both breads are positive (8.9 and 8.2), with a tendency also to decrease yellow shades but in a lower proportion than with respect to the a* color dimension, with only 8%, related to the presence of carotenoids, as suggested by some studies examining yellow food products who have reported b* to be an important predictor of carotenoid content [58, 59]. The L* value of the bread made with the germinated seedlings decreased significantly after 5 days of germination, by a percentage of 6%.

***Table 7*:** Lentil sprout bread and its color components.

Optical image of germinated lentils (LG)	Bread	Spectrum	L*	a*	b*	GI
 a). 2			27.9	2.7	8.9	47
 b) 5			26.1	1.8	8.2	10

G_{max}: Glycemic response max; LG: Lentil germinated.

Among the color coordinates, the dimension a* showed the greatest change. Similarly, the colour parameters hue, chroma, whiteness index, yellowness index, color differences and browning index tended to decrease when the bread was made with sprouts for 5 days (17, 15, 7, 3 and 15.5%). It can be observed that the color parameters that changed the least when the number of days of germination was varied were the variables representing the whiteness index and the yellowness index (Table 8).

Table 8**:** Bread color and associated parameters

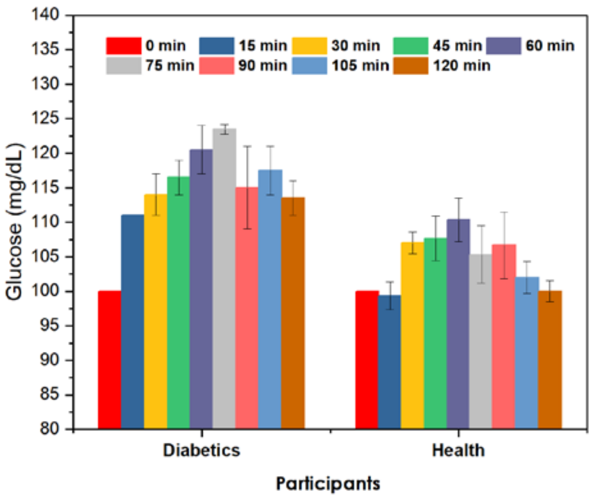
Description	Equation	Bread G1	Bread G2
Tono	$h_{ab} = arctan\left(b^*/a^*\right) C_{ab} = [(a^*)^2 + (b^*)^2]^{1/2}$	L*:27.9 a*: 2.7 b*:8.9	L*: 26.1 a*:1.8 b*:8.2
Croma	$C_{ab} = \frac{[(a^*)^2 + (b^*)^2]^{1/2}}{arctan\left(b^*/a^*\right)}$	$h_{ab} = 11.86$ $C_{ab} = 7.28$	h_{ab} =9.86 C_{ab} =6.19
Índice de blancura	$IB = 100 - [(100 - L^*)^2 + (a^*)^2 + (b^*)^2]^{1/2}$	IB = 27.30	IB = 25.62
Índice de Amarillez	$IA = \frac{142.86\, b*}{L}$	IA = 45.57	IA = 44.88
Diferencias en color	$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$		ΔE = 4.19
BI (Browning index)	$BI\ (\%) = \frac{y - 0.31}{0.172}\ x\ 100$ $y = \frac{1.75L* + a*}{a* - 3.012b* + 5.645\ L*}$	BI =14.41	BI =12.19

3.2.2 Glycemic Response to Bread Consumption

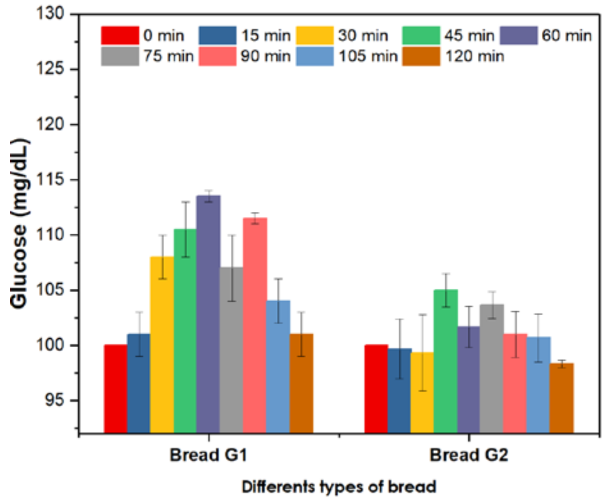
Figure 5 shows the basal (before eating the bread) and postprandial glycemic response to the consumption of germinated lentil bread, measured every 15 min. It can be observed that the diabetic participants reach a higher level of glucose compared to the healthy participants. The increase in glucose is gradual, creating a flattened curve for both diabetics and healthy participants.

The maximum average value reached by diabetics is 60 and 75 min (Figure 5a), and for the healthy participants it is reached at 60 min. The increase in glucose is 25 and 15 mg/dL for the diabetic and healthy participants, respectively, when consuming 50 g of sprouted lentil bread.

Other researchers have observed that the rapidly digestible and resistant starch in lentils is closely associated with a lower blood glucose response [60].



(a)



(b)

Figure 5: Glycemic response due to lentil bread consumption a) diabetic and healthy participants and b) healthy patients with different types of bread made with germinates for 2 (bread G_1) and 5 (bread G_2) days

3.2.2 Estimation of Glycaemic Index of Lentil (germinated) Bread

The calculation of the glycemic index of the lentil bread after 2 (bread G_1) and 5 (bread G_2) days of germination processing was based on the calculation of the area under the curve (Figure 6) a) Pure glucose, b) glucose of bread G_1 and c) glucose of bread G_2. It is possible to see how the area under the curve decreases as a function of the number of days of the germination of the lentil that is used in bread making, which produces a lower postprandial response. The germinated lentil bread with chia has the property of satisfying hunger, but it also has a low glycemic index. Furthermore, it has been reported by several authors to have sensory acceptability in the population, for both chia and lentils.

The value found for bread made with lentils germinated for two days had a GI_L of 47, while bread made with lentils germinated for 5 days had a GI_L level of 10 (Table 9). In the study by [60], 20 types of lentils were evaluated and 8 of them were found to have a low glycemic index. When compared to the starch content of white bread, lentils were found to be high in resistant starch and white bread was found to be low in resistant starch. The glycemic index of lentils ranged from 10 to 23, while that of white bread was 71. Our study shows that lentil sprouts, in combination with chia, can be used to make bread for diabetics. According to the literature, the lentil germinated increases the phenol and flavonoid content and decreases the saponins, making them suitable for consumption [35]. Lentil germinated are one of the options that should be consumed by the Mexican population to prevent diabetes and diseases related to the metabolic syndrome, using them as a main element in foods such as bread. One of the main requirements for bread is its cost. Lentil germinated are easy to produce and inexpensive.

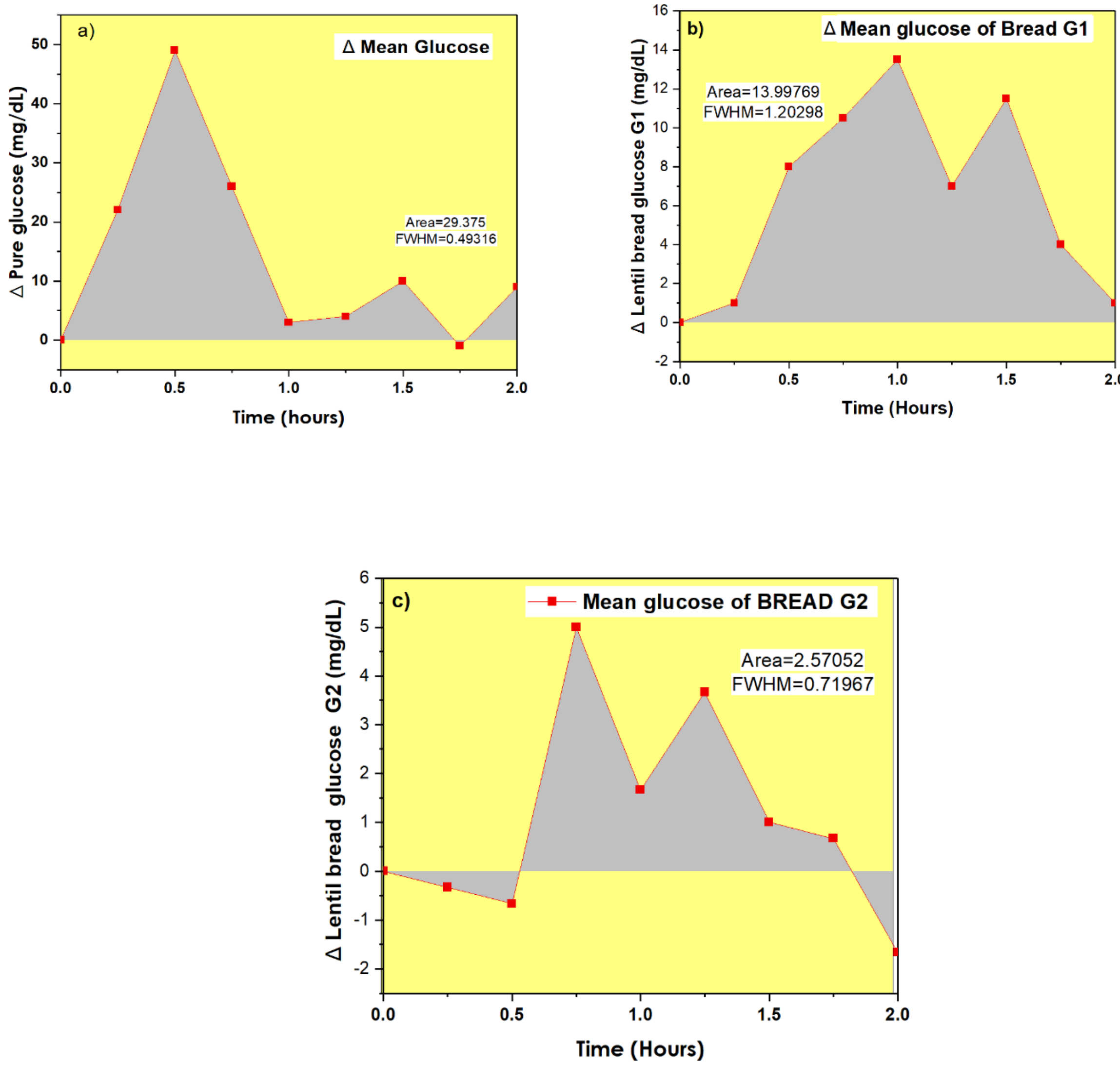


Figure 6: Area under the postprandial curve for healthy participants. a) Glucose pure, b) Glucose bread of lentil G_1 and c) Glucose of bread of lentil G_2

Table 9: Calculation of the glycemic index of lentil bread.

Glucose or bread type	Points that form postprandial response curve (glucose increase)	Area under curva	Glycemic index
		$A \approx (h/2)(y_0 + 2y_1 + 2y_2 + ... + 2y_{n-1} + y_n)$	**GI = (ABG1 / APG) x 100**
Glucose h = 0.25 (interval between each point)	<u>x y</u> 0 0 0.25 22 0.5 49 0.75 26 1 3 1.25 4 1.5 10 1.75 -1 2 9	A ≈ (0.25/2) (0 + 2(22) + 2(49) + 2(26) + 2(3) + 2(4) + 2(10) + 2(-1) + 9) A ≈ (0.125) (0 + 44 + 98 + 52 + 6 + 8 + 20 - 2 + 9) ≈ (0.125) (235) ≈ 29.375	Reference Area: 29.375
Bread G_1 (using germinated lentil to two days)	<u>x y</u> 0 0 0.25 1 0.5 8 0.75 10.5 1 13.5 1.25 7 1.5 11.5 1.75 4 2 1	A ≈ (0.25/2) (0 + 2(1) + 2(8) + 2(10.5) + 2(13.5) + 2(7) + 2(11.5) + 2(4) + (1)) ≈ (0.125) (0 + 2 + 16 + 21 + 27 + 14 + 23 + 8 + 1) ≈ (0.125) (112) ≈ 14	**GI = (ABG1 / APG) x 100** IG_1 = (14 / 29.375) x 100 ≈ 47.3 %
Bread G_2	<u>x y</u> 0 0 0.25 -0.33 0.5 -0.66 0.75 5 1 1.66 1.25 3.66 1.5 1 1.75 0.66 2 -1.66	A ≈ (0.25/2) (0 + 2(-0.33) + 2(-0.66) + 2(5) + 2(1.66) + 2(3.66) + 2(1) + 2(0.66) + (-1.66)) ≈ (0.125) (0 - 0.66 - 1.32 + 10 + 3.32 + 7.32 + 2 + 1.32 - 1.66) ≈ 2.5 ≈ (0.125) (20) ≈ 2.5	**GI = (ABG2 / APG) x 100** IG_2 = (2.7 / 29.375) x 100 ≈ 8.5%

Considering preventive models based on low glycemic response foods is relevant in countries with potential risk of developing diabetes such as some in the Americas, including Mexico.

Preventive models have been proposed to prevent diabetes, because type 2 diabetes has prior manifestations of insulin resistance [61], caused by consumption of carbohydrate-rich foods, hence high glycemic response. Therefore, the food choices of the population are a key factor in the prevention of diabetes. Diabetes prevention models based on these strategies have been reported in some countries. Most prevention models are based on diet, exercise and the use of hyperglycemic agents. Diets should be aimed at consuming foods with a low glycemic index.

In Sweden, a diabetes prevention program was implemented in the population of Malmö using dietary advice and increased physical activity as intervention strategies; smokers were not included in the reported studies. The dietary and/or physical activity interventions led to a significant reduction in the incidence of diabetes among people with impaired glucose tolerance over a 6-year period. There were also reductions in body weight, body mass, and hyperlipidemia. Of note, there was an increase in triglycerides in the reference group [62].

In a population of Da Qing, China, [63] conducted a model of type 2 diabetes prevention. Their proposed prevention strategies were diet, exercise, and diet-exercise. The diet consisted of 25-30 kcal/kg body weight (105-126 kJ/kg), 55-65% carbohydrate, 10-15% protein, and 25-30% fat. The authors found that diet was more important than exercise in preventing diabetes. However, the results were much better when the two were combined, as the rate of diabetes development was further reduced. The importance of diet has been reported; there have been cases where people who exercise but do not have a proper diet can develop diabetes because of the high carbohydrate diet they eat.

Diabetes awareness and prevention education was carried out from the earliest stages of schooling, such as primary school in New Delhi, with primary school students from government and private schools. Diabetes prevention education was conducted over a period of 5 months. Fun learning games, worksheets and school competitions such as poster making were structured as an extension of classroom activities. Students were encouraged to practice what they had learned. Diabetes knowledge was taught, and exercise and a diet based on fruit and vegetables were encouraged. The authors found a decrease in junk food in both public (13.8%) and private (6.5%) schools. Fruit juice consumption also decreased. The biggest changes occurred in girls compared to boys [64].

Also in India, a lifestyle modification program was implemented in the diabetic community. In this program, they promoted the use of a lifestyle program and appropriate supplementation of oral hypoglycemic agents, using lifestyle + metformin when necessary. Participants meet with a physician and dietitian, attend classes (related to diabetes prevention through weight loss and diet (focus on fat reduction) and exercise (using water bottles), receive educational brochures, and reinforce prevention through increased physical activity. It is a low-cost program that can be used in low-income countries, and participants are followed for 36 months [65].

In East Harlem, New York [66], a diabetes prevention model was established among youth who participated in the design of the model. Youth input for the model was categorized into several themes: (1) the impact of diabetes on the quality of life within youth's personal networks; (2) conflict between diet and activity change and their current lifestyle; (3) lifestyle choices are dictated by cost, mood, body image, and environment, not health; and (4) family, social, and environmental pressures that reinforce sedentary behaviors and unhealthy diets. Features of a prevention program should include additional social support, face-to-face workshops using tools such as text messaging and social networking, methods to create a learning environment and encourage participants without being disrespectful, maintaining confidentiality, focusing on healthy eating and active living rather than weight loss *per se*, having a good relationship with peer leaders, not diving too deeply into sensitive topics, and providing interactive activities.

A nutrition education program (NEP) was implemented in Brazil. In the study reported [67], individual treatment and group counseling were provided by a team of nutritionists. The dietary intervention consisted of a group discussion format. The intervention included written and oral didactic instructions to improve diet quality (consumption of more vegetables, fruits, whole grains, and less saturated fat). Several risk factors for developing type 2 diabetes mellitus decreased in Brazilians with glucose intolerance.

Diets of GI_L could be part of a diabetes prevention model, especially diets in which traditional bread is replaced by a low glycemic index bread, as proposed in this study, based on sprouted lentils and chia. Several epidemiological studies have reported the benefits of dietary polyphenols, which could be used in the prevention and treatment of type 2 diabetes and insulin resistance due to their antidiabetic properties.

Thus, several authors agree on the importance of diet and food selection in disease prevention. Among the foods with the highest glycemic impact are those with a high carbohydrate content. In general, foods based on wheat, rice, and corn without added fiber or protein produce a high glycemic response. Among the foods with the highest glycemic response in Mexico are tortilla and bread; in general, it is a diet based on corn, wheat and rice. These cereals have a high postprandial response.

“Let food be your medicine and medicine be your food” (Hippocrates).

A diabetic food design is proposed in this research: Bread, a staple food in many parts of the world, is typically prepared by mixing four ingredients: wheat, water, salt, and yeast in varying proportions. Apart from these primary ingredients, the incorporation of functional ingredients that provide health benefits in bakery products has become widespread due to the increasing consumer demand for functional foods.

Several studies have shown that bread containing functional ingredients and antioxidants are associated with health maintenance and reduced risk of some chronic and degenerative diseases, obesity, inflammatory diseases, and aging. A remarkable increase in dietary fiber, phenolics and flavonoids was observed in bread with 5% lavender and lemon balm residues [68]. Bread supplemented with 5% green coffee increased phenolic and antioxidant activity [69]. Higher levels of phenolic compounds and dietary fiber have also been reported in bread enriched with chia seeds (*Salvia hispanica*), pomegranate seeds four, rosehip seeds four, hemp seeds four, yam (*Dioscorea opposita Thunb*), aerial parts of sweet potato, and black carrot fiber [70-76]. In the present research, bread made with lentil sprouts and chia is proposed as a new bread design for consumption by diabetics. Which enhances the beneficial properties of both functional products. In the case of chia, also, it has been reported to have glucose-lowering properties.

The prevention of diabetes through the consumption of foods with a low glycemic index or a low postprandial response is a culture that must be developed in our societies to avoid the deterioration of quality of life and the excessive consumption of medicines that, when the disease develops, are the only option for survival. In the case of poor communities, this becomes a vicious cycle that prevents them from escaping poverty. Governments should take care to promote educational models in the world where people learn to choose foods with a low postprandial response to have a sustainable future.

Diabetes has been the leading cause of death among women and the second leading cause of death among men in Mexico since 2000. Between 2000 and 2010, mortality from diabetes increased by 22.2% in men and 17.1% in women. By 2020, the mortality rate will have risen dramatically to 11.95 per 10,000 inhabitants, accounting for 14% of all deaths in the country. The problem is particularly acute in the poorest states, where mortality trends have changed significantly; between 2005 and 2014, mortality decreased for women, but more slowly for men. The prevalence of diabetes has also increased, from 7.3 million cases in 2006 to 12.8 million in 2020, and is projected to reach 21.2 million by 2045 [77].

Globally, metabolic risks - such as high body mass index (BMI) - and behavioural factors - poor diet, smoking, and low physical activity - have contributed to many deaths from diabetes. These estimates are crucial for formulating policy and allocating resources to prevent and treat the disease. Up to 13 risk factors have been identified, including metabolic, environmental and behavioral factors. The latter are particularly relevant in the Mexican context, where high consumption of processed foods and sugars, generally high in carbohydrates, has exacerbated the diabetes crisis [78].

It is therefore important to develop new products with a low glycemic index to shape the diets of pre-diabetics, diabetics and healthy people. For the non-diabetic or insulin resistant population, they would have the opportunity to change the direction of dietary trends towards a low glycaemic index diet and added functional foods. This is clearly a systemic problem; for example, ethnic differences play a significant role in the prevalence of type 2 diabetes. One study has shown that in both indigenous and non-indigenous populations, the likelihood of developing the disease increases with age and BMI. Interestingly, those living in rural areas are less likely to have type 2 diabetes than their urban counterparts.

A network of interconnections of the diabetes problem can be seen in Figure 7 through a representation of interconnections of causes and impacts. Awakening consciousness is part of academic education, but it is also a spiritual education that teaches the development of being in people and how to distinguish between good and bad for their lives [79-81]. Thus, transdisciplinarity is becoming more and more necessary in this globalized world [82]. Choosing Foods with a low glycemic index is a challenge for the future.

4 Conclusion

A new bread design for diabetics could be based on lentils sprouted for two to five days, with the addition of chia for better texture. Lentil sprout bread with chia results in a low glycemic index bread. The use of food design methods is essential to identify and consider the needs of the population to make the best choices about the ingredients to include. A culture of eating based on postprandial response or glycemic index will be needed for populations at potential risk of developing diabetes or seeking a sustainable lifestyle.

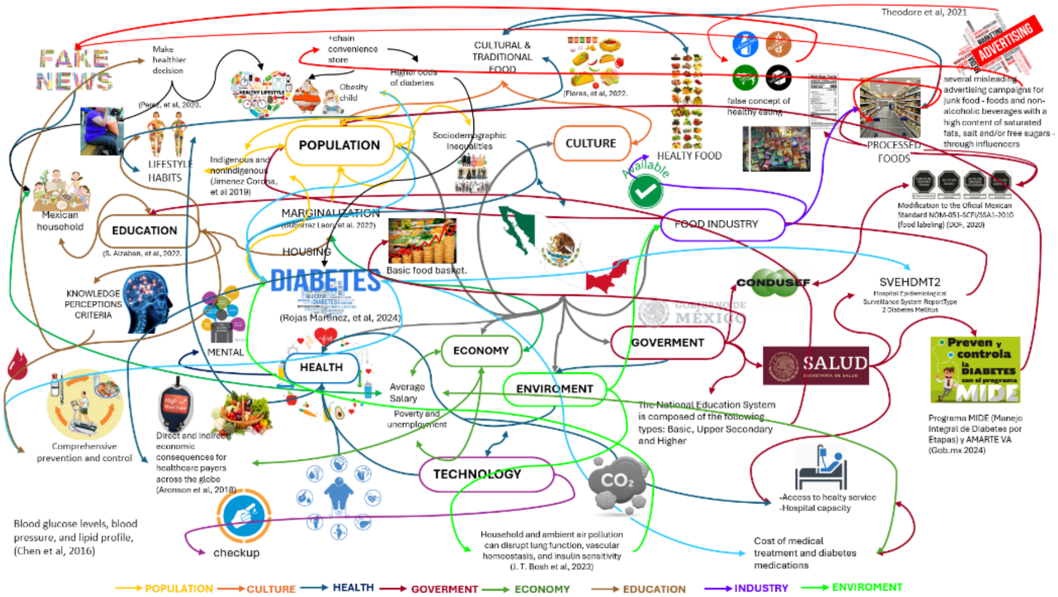


Figure 7: A systemic view of the diabetes problem

Authors' Contribution:

CHA had the idea for the research, proposed the methodology and carried out the research and manuscript preparation. JEVH collaborated in the research and application of the QFD methodology and the systematic analysis of the diabetes problem, FADP collaborated in the experimental research, interpretation and analysis of some data and critical revision of the manuscript. MVCP, MFC, ACO, collaborated in the interpretation and analysis of some data and critical revision of the manuscript, YCTT collaborated in the research.

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