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Development of vegan, gluten-free macarons using *Artocarpus heterophyllus* Lam. (jackfruit) incorporated with wheatgrass powder

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Abstract

Artocarpus_heterophyllus Lam. is commonly referred as jackfruit. A widespread fruit in Asia, Africa, and some parts of South America, jackfruit is a tropical climacteric fruit that is native to India's Western Ghats and is a member of the Moracae family. Jackfruit is a nutritious, high-energy food. The freshly sprouted initial leaves of the *Triticum aestivum*, a species of common wheat, are used as a food, beverage, or dietary supplement known as wheatgrass. Therefore, this study was aimed to develop a portable, nutritious, ready-to-eat jackfruit product (macaron) incorporated with wheatgrass powder and to evaluate the nutritional properties of the product. Flour made from jackfruit and almond flour were utilized for the development of macarons. Egg white was replaced by aquafaba. Aquafaba is the viscous water in which legume seeds such as chickpea have been cooked. It forms stable edible foams and emulsions with functional properties which are similarly produced by whole egg and egg white. Three different formulations were prepared. Sample 1 (F_1) received rating of liked extremely as per 9-point hedonic scale. Analysis of macaron reveals that the jackfruit macaron is high in carbohydrates (95.56 g) and low in fat (0.27 g). Thus, jackfruit macaron is an appealing and inexpensive vegan and gluten-free food source for vegetarians and consumers with animal protein allergies and allergic to gluten respectively.

Keywords: Jackfruit; Wheatgrass powder; Aquafaba; Macarons; Vegan

1. Introduction

The development of human civilization, plays an important role in domestication of plant species which can be used as a source of food, medicine, flavoring, timbers, fruit, vegetables, firewood and animal feed in addition to other applications [1]. The Moraceae family includes jackfruit-producing trees, such as *Artocarpus heterophyllus* Lam. They are thriving in Bangladesh, India, and numerous other Southeast Asian nations [2]. The jackfruit tree is an evergreen that yields more than any other kind of fruit tree and provides the largest edible fruit (up to 35 kg) [3]. The jackfruit is a huge tree with a height of 10-15 m that is native to evergreen forests at an altitude of 450–1200 m and is grown all over India's hotter regions. This plant's stem is straight, but its bark is green or black and exudes milky latex [4]. The fruit consists of edible seeds, rind, and yellow-fleshed bulbs. It is either consumed directly or processed into chips and snacks to be consumed later [5]. The fully formed perianths, or "bulbs" as they are known in botany, of jackfruit are its edible sections. Each bulb has a seed that is covered in a thin, white exocarp and is grouped together among long, slender ribbons of rough, underdeveloped perianths. The net edible portion of the jackfruit bulb, which excludes the seed and exocarp, is referred to as the "flake." For every 100 g of ripe fruit flakes, there are 18.9 g of carbs, 0.8 g of minerals, 30 international units (IU) of vitamin A, and 0.25 mg of thiamine. Even though the jackfruit is rich in nutrients, it is unsuitably referred to as "Poor man's food" in eastern and southern India [6,7]. Since it is a monoecious tree, both male and female inflorescences can be found on it. Cross-pollination is used for fertilization, and seeds are mostly used for seed production. Depending on the country, the entire fruit growth process can take anywhere between three and seven

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months from the time of pollination [8]. The jackfruit's fruit, tree, and branches have a plethora of advantages. The fruit is filled with a variety of nutrients. The lignans, flavones, and saponins found in jackfruit have anticancer, antiulcer, antihypertensive, and antiaging effects. The fruit is a good source of dietary fibre, vitamins, minerals, carboxylic acids, and carbohydrates. Because the seed is high in lectins, calcium, iron, magnesium, potassium, manganese, and potassium, it satisfies the nutritional needs of rural people [9]. Asthma, ulcers, indigestion, tension, nervousness, and constipation can all be treated with jackfruit. Per kilogram of wet weight of ripe perianth, jackfruit supplies about 2MJ of energy [10].

As a reserve carbohydrate, starch is extensively dispersed in a variety of plant species and is particularly prevalent in cereal grains, legumes, tubers, and young fruits. Amylose (20–30%) and amylopectin (70–80%) are the two major macromolecules that make up this compound. They are linked by hydrogen bonds [11]. Humans get their carbohydrates mostly from starches, which are now used in a range of food products as thickeners, stabilisers, gelatinizers, fillers, superabsorbent polymers, and adhesives [12].

In the majority of nations, wheat (*Triticum aestivum*) is a key component of the nutrition of people. Numerous epidemiological studies have suggested that increasing the consumption of whole grains and whole grain products can help prevent chronic illnesses [13]. Wheatgrass is the term for the earliest sprouting leaves of the common wheat plant. Wheatgrass has flat, narrow, 20-38 cm long, and 1.3 cm wide leaves that are around 1.2 m tall, simple, hollow or pithy, and glabrous. The spikes are long, thin, compressed dorsally, and slightly flattened. Wheatgrass is incredibly nutrient-dense, containing (per 3.5 gram) 860 mg of protein, 18.5 mg of chlorophyll, 15 mg of calcium, 38 mg of lysine, 7.5 mg of vitamin C, and rich in micronutrients such as B complex vitamins and amino acids [14]. Due to the rising demand for foods high in antioxidants, wheatgrass has become more widely known and is now offered in beverages, pills, and powder form. These antioxidant-rich goods prevent ageing and shield us from degenerative conditions like cancer and Alzheimer. The body need a balanced diet rich in proteins, minerals, and vitamins to maintain proper function [15]. Chlorophyll has been suggested as a key dietary chemopreventive agent because of its structural similarities to bilirubin and haemoglobin. Another intriguing element of wheatgrass that reverses the effects of oxidative stress and lowers the prevalence of numerous degenerative diseases and disorders are the phenolic chemicals [16].

The nutrients a food contains determine its biological value. The nutritional value of proteins mostly depends on their amino acid makeup, particularly how many essential amino acids they contain. Proteins play a role in food's organoleptic qualities in addition to their necessity for diet. Food texture is influenced by proteins, while flavor is influenced by small peptides and amino acids. When food is prepared and stored, proteins, peptides, and amino acids go through heat and enzymatic processes that result in colorful aromatic molecules [17]. Wheatgrass contains at least 17 different types of amino acids consisting eight of the nine essential amino acids. Aspartic acid, glutamic acid, arginine, ala-nine, and serine are only a few of the abundant amino acids found in wheatgrass, which is another noteworthy characteristic [18,19]. Wheatgrass-enriched foods can be suggested to the people for both general well-being and the treatment of illnesses like metabolic syndrome, cancer, thalassemia, anaemia, etc. [20].

1.1. Food diversification

Food diversification is a strategy to expand the supply of different foods generated from local resources, to fulfil consumer demand for a varied range of nutritiously balanced and safe foods, to grow the food industry, and/or to enhance community welfare. In other words, diversification will be advantageous if it is possible to maximize the potential of already available local food. Food produced locally for economic or dietary reasons is referred to as local food.

The arrangement of the different and general type of food components that people in a population usually consume over the course of a particular amount of time is referred to as the food consumption pattern [21].

Animal supplies including meat, milk, and eggs are progressively being imitated and replaced by plant-based food ingredients and goods. The exponential growth of the vegetarian and vegan markets, as well as consumer preferences for nutritious and ecofriendly foods, are all factors contributing to this trend. Among the 20–30% of proteins rich in lysine that are found in pulses include dry beans, chickpeas, faba beans, lentils, and dry peas. As a result, replacing animal protein in the diet can be largely accomplished by the use of pulses, the edible dry seed of legumes. When pulse seeds are canned or cooked in water, a solution is created that can be used in food compositions as a plant-based rheological ingredient after being separated from the seed. This solution is called as "aquafaba" [22]. A few years ago, when investigating for vegan alternatives to eggs to prepare meringues, researchers found the useful characteristics of the wastewater produced during the boiling of chickpeas. The term "aquafaba," which refers to both the liquid from bottled chickpeas and the boiling water from chickpea products, originates from the Latin word for both water (aqua) and beans (faba) [23]. Egg is widely used in food products to provide softness, color, and texture, especially in baked products, dairy desserts, noodles, and pasta. Due to their high surface-active capabilities, egg whites are capable of foaming and emulsifying. As a result, they act as emulsifiers, bind components, whip into foams, and coagulate when heated. For their foaming and emulsifying qualities in vegan and gluten-free food products, pulses protein isolates and flour have been analyzed [24]. The market for desserts is expanding annually, and consumers love macarons for their variety of shapes and colors in addition to their sweetness. Almond powder is incorporated as one of the primary ingredients of macarons, along with egg whites and sugar powder, creating them a soft and voluminous feel [25].

Celiac disease (CD) is a chronic immune disorder of the small intestine triggered by gluten ingestion. The most prevalent and growing food intolerance, CD, affects about 1% of people globally [26]. As more people are diagnosed with celiac disease and other gluten-related illnesses such dermatitis herpetiformis, gluten ataxia, wheat allergy, and non-celiac gluten sensitivity, the market for gluten-free bread items is expanding significantly. Following a strict, permanent, lifelong gluten-free diet is now the only effective and safe treatment for these kinds of diseases [27]. Nuts are renowned for being a rich source of lipids and other nutrients. In humans, total and LDL cholesterol levels have been shown to be dramatically reduced when nuts are used to replace half of the daily fat intake. The most widely consumed tree nut in the world and the most produced tree nut, almonds (*Prunus amygdalus*) are a member of the Rosaceae family, which also includes apples, pears, prunes, and raspberries. The edible almond fruit (*P. amygdalus*), which resembles a peach, has three different bits: the interior kernel or meat, the center shell section, and the outside green shell cover or hull. Almond types are classified as hard or soft shelled based on the texture of their shells [28]. A range of benefits are added to food products when almonds are included in them. Nutritious value (protein, lipids, minerals, vitamin E, and fiber), a desirable texture (like the crispy texture of toasted almonds), and flavor (nutty and sweet) qualities are only a few of the significant contributions produced by almonds to a food product [29]. Sugar is divided into two parts for the purpose of manufacturing macarons. The first is the granulated sugar (caster sugar) that is added for making meringue. The second is confectioners' sugar (icing sugar) combined with almond powder. Sugar is an essential ingredient in macaron shells since it enhances the flavor and structural integrity of the final product. Granulated sugar is typically thought to strengthen meringue whereas confectioner's sugar adds lightness to the texture. Since sugar levels are high, reducing them is necessary to create a healthy macaron. However, in addition to providing sweetness, sugar also serves as a functional element that affects the shape, texture, and flavor of macarons. [30].

2. Material and methods

The present study entitled "Development of vegan, gluten-free macarons using *Artocarpus heterophyllus* incorporated with wheatgrass powder" was carried out in the Department of Food Technology, Parul Institute of Applied Sciences, Parul University, Vadodara. The materials utilized are listed in this part, along with a description of the processing methods, organoleptic testing, and analytical procedures employed in the study.

2.1. Materials

2.1.1. Raw materials used in study

The components utilized to make vegan, gluten-free macarons include jackfruit flour, wheatgrass powder, aquafaba, almond flour, icing sugar, caster sugar, egg white and gel food color.

2.1.2. Chemicals and Glassware's

Sufficient glassware and chemicals for analytical grade are available in the department of Food Analysis and Food Processing lab, Department of Food Technology, Parul Institute of Applied Science, Parul University, Vadodara.

2.1.3. Processing Equipment

Equipment required for the preparation of vegan, gluten-free macarons are: Weighing balance, oven, grinder, silicon baking sheet, electric beater and other utensils were obtained from Food Processing Lab, Department of Food Technology, Parul Institute of Applied Sciences, Parul University, Vadodara.

2.2. Methods

2.2.1. Physio-chemical Analysis

Jackfruit flour, wheatgrass powder, aquafaba, almond flour, icing sugar, caster sugar, egg white and gel food color were used to prepare vegan, gluten-free macarons and were examined for proximate composition including moisture, ash, protein, fat, carbohydrate, and calories content as per the standard procedure given by (AOAC 2005).

Moisture content

After thoroughly drying the empty dish, 5 g of the sample was weighed and ground in the dish to determine its moisture content. The dish was then placed in an oven to dry for 4 hours at 105 °C. After cooling in the desiccator to a consistent weight, it was weighed once again. Moisture content was estimated from the weight loss that resulted.

$$\text{Moisture \%} = \text{Initial weight (W1)-final weight(W2) / Initial weight (W1)} \times 100$$

Ash content

The (AOAC 2005) technique was used to calculate the ash content. A pre-weighed crucible containing 5 g of sample was filled with the sample, which was then heated at a low flame until all of the material was totally charred (smokeless) and cooled. The sample was then maintained at 550 °C in the muffle furnace for approximately 4 hours. It was weighed after being cooled in desiccator one again. The process was continued until the weights of two successive trials remained constant. Knowing the difference between the initial and final weight ash content was calculated.

$$\text{Ash \%} = \text{Weight before heating} - \text{Weight after heating/ Weight of sample} \times 100$$

Determination of Protein content:

Protein content was determined by Micro-Kjeldhal method.

- Digestion

200 mg of the defatted ground sample was precisely weighed, and then a small amount of the catalyst K_2So_4:$CuSo_4$:HgO red (91:8.2:0.8 g) was added. The sample was then transferred to the digestion flask, where it was digested for a couple of hours at 45 °C with 5ml of concentrated H_2So_4 until the substance became colorless.

- Neutralization and Distillation

The digested sample was diluted to a final volume of 50 ml with distilled water in a volumetric flask. The 5ml aliquot was then neutralized using a solution of 30% HCl and 40% NaOH containing 5 g of sodium thiosulfate. Ammonia that had been released during the distillation process was absorbed in a solution of 2% boric acid and methyl red to act as an indicator.

- Titration

The ammonia that had been collected was titrated against 0.01N H_2SO_4. The titer reading was recorded, nitrogen was calculated using the formula given below, and protein percentage was determined by multiplying by 6.25. A blank sample was also performed simultaneously.

$$\text{Crude Protein \%} = (\text{Sample titre} - \text{Blank titre}) \times 0.0014 \times 6.25 / \text{Sample weight} \times 100$$

Crude Fat

Soxhlet was used to analyze the fat content of vegan, gluten-free macarons. A sample of 5 g was measured and taken in a thimble. The extraction cups were weighed after being dried in an oven at 130° C for 15 minutes. After cooling the extraction cups, 70 ml of petroleum ether was added. The apparatus was preheated, and once the desired temperature was reached, the extraction cups were attached to the apparatus and set to boil for 30 minutes, rise for 20 minutes, and then recover solvent for 10 minutes. The recovered ether was collected, and the amount of fat in the extraction cups was calculated.

$$\text{Fat} = (W2 - W1) / W \times 100$$

Determination of Carbohydrates:

The amount of carbohydrates was determined by subtracting the total amount of moisture, fat, protein, total ash, and crude fibre. The formula below was used to determine the NFE.

$$\text{NFE \%} = 100 - (\text{CP\%} + \text{CF\%} + \text{CF\%} + \text{TOTAL ASH\%})$$

CP = crude protein, CF= crude fat, CF= crude fiber

2.3. Microbial Parameter

Microbial analysis is the ideal quality evaluation protocol used in food product quality analysis. Prepared vegan, gluten-free macarons were tested for their microbiological quality. Different microbiological parameters, including Total Plate Count, Yeast, and Mould, were evaluated in the current study. Additionally, the samples were checked while they were kept at room temperature. Microbial tests were performed using the APHA's recommended procedures (1992).

2.3.1. Determination of total plate count.

- Preparation of nutrient agar medium: In 1000 ml of distilled water, 28 g of nutrient agar was added, and the mixture was boiled until the agar properly dissolved. It was sterilized in an autoclave for 20 minutes at 120 °C and 15 lbs of pressure with its mouth plugged with cotton.
- Preparation of sample solution (serial dilution): Nine sterile test tubes were taken and given numbers. 9 ml of distilled water were poured into each tube. The test tubes were sealed with cotton plugs and sterilized in an autoclave at 121 °C for 15 minutes under 15 lbs of pressure. A sterile test tube containing 9 ml of distilled water had 1ml of sample added to it serially.
- Pipettes and Petri dishes were sterilized using an autoclave (moist heat treatment) or a hot air oven (dry heat treatment). The laminar airflow cabinet was filled with sterilized petri dishes, and an ultraviolet light was turned on for 30 minutes. After 30 minutes, the UV light was turned off, and after that, the fan was turned on and 70% ethanol was used to clean the work surface. After plates had been appropriately labelled, 1ml of samples were poured to each plate. Each plate received 15–20 ml of molten media. To avoid microbial contamination of the plate, this was carried out near to a flame. The plates were vigorously stirred and then kept to solidify. After 48 hours at 37 °C in the incubator, the plates were taken out to be checked for colonies.

2.3.2. Determination of Yeast and Mould count

- Preparation of potato dextrose agar medium: 1000 ml of distilled water was added, along with 39 g of potato dextrose agar medium, and boiled until well dissolved. It was sterilized in an autoclave at 121 °C for 15 minutes under 15 lbs of pressure using a cotton plug to seal the mouth.
- Preparation of sample solution (serial dilution): A total of nine sterilized test tubes were taken and numbered. In each tube, 9 ml of distilled water was added. The test tubes were sealed with cotton plugs and sterilized in an autoclave for 15 minutes at 121 °C and 15 pounds of pressure. Serially, 1ml of the sample was added to 9 ml of distilled water in the sterile test tube.
- Preparation of plates: Pipettes and Petri dishes were either autoclaved (moist heat treatment) or heated in a hot air oven (dry heat treatment) for sterilization. In a laminar air flow cabinet, sterilized petri dishes were placed, and an ultraviolet light was turned on for 30 minutes. The working surface was cleaned with 70% alcohol when the UV light was turned off after 30 minutes and the blower was turned on. After properly labelling the plates, 1ml of the samples were poured to each plate. Each plate received 15–20 ml of molten medium. To avoid microbial contamination of the plate, this was done close to a flame. The plates were vigorously stirred and then kept to solidify. The colonies on the plates were then inspected after the plates had been in the incubator for 48 hours at 37 °C. On the plate, the former colonies were enumerated.

2.4. Preparation of Vegan, Gluten-free Macarons-

Table 1 Formulation of developed product

Composition (g)	**Formulation**		
	F_0 (control)	**F_1**	**F_2**
Jackfruit flour	0	54	55
Wheatgrass powder	0	1	0
Almond flour	55	0	0
Aquafaba	0	39	39
Egg white	39	0	0
Caster sugar	33	33	33
Icing sugar	55	55	55
Food color (drops)	2-3	2-3	2-3

55 g of jackfruit flour, 1 g of wheatgrass powder, 39 g of aquafaba, 33 g of caster sugar, 55 g of icing sugar and gel food color make up the various ingredients used in the standardized formula for making the vegan, gluten-free macarons. Jackfruit flour, wheatgrass powder and icing sugar were sieved before mixing. Aquafaba was whipped using electric beater. During whipping caster sugar was added in two batches and then gel food color was added. Sieved dry mixes were added to the whipped cream and mixed using spatula. Round shapes were made with mixture on grease-free baking sheet and baked at 180 °C for 30 minutes. Prepared vegan, gluten-free macarons were kept into airtight container and preserved in the refrigerator for longer shelf life.

3. Results and discussion

The result obtained during investigation "Development of vegan, gluten-free macarons using *Artocarpus heterophyllus* incorporated with wheatgrass powder" is discussed here. In all of the chosen formulas, almond flour macarons containing egg white were served as the foundation for the macarons. The final product was analyzed for Physicochemical analysis, microbial analysis, sensory evaluation and stored in refrigerator. Research experiments undertaken to standardized the method for manufacturing of vegan, gluten-free macarons have been discussed under heading follows

3.1. Proximate composition of Vegan, Gluten-free Macarons

Three distinct vegan, gluten-free macarons formulations- control sample, sample 1 and sample 2 were developed. Main ingredients or jackfruit flour and wheatgrass powder were eliminated from the control sample for reference purpose. Jackfruit flour and wheatgrass powder were combined in sample 1 in a 54 : 1 ratio, whilst wheatgrass powder was not added in sample 2. Sample 1 was particularly appreciated based on proximal analysis and sensory analysis. The excellent formulation was achieved with a 54 : 1 ratio of jackfruit flour to wheatgrass powder.

3.2. Microbial analysis of vegan, gluten-free macarons

3.2.1. Total plate count (TPC) of vegan, gluten free macarons:

The total plate count recorded in vegan, gluten free macarons is 17,700 cfu/g i.e., 4.2479 Log_{10} cfu/g.

3.2.2. Total yeast and mould count of vegan, gluten free macarons:

The total yeast and mould count observed in vegan, gluten free macarons is<10 cfu/g.

3.2.3. Escherichia -coli detection in vegan, gluten free macarons:

The vegan, gluten free macarons test results demonstrate 0% *E. coli*.

3.3. Sensory evaluation of vegan, gluten free macarons

Table 2 Sensory evaluation of produced vegan, gluten free macarons

Sr. No.	Sample code	Appearance	Color	Texture	Taste	Overall acceptability
1	F_0: Control sample	8	8	7	7	7.5
2	F_1: Sample 1	9	9	8	9	8.75
3	F_2: Sample 2	7	6	7	8	7

The quality of the vegan, gluten-free macarons was significantly influenced by their flavor, texture, and taste. The flavor and color of the macaron undergone tremendous changes as a result of variations in the concentration of the raw ingredients. On the basis of appearance, color, texture, and taste, macarons were given a score of 8, 8, 7, and 7 for the control sample (F_0). The control sample received a remarkable 7.5 hedonic ratings for overall acceptability, indicating that it is liked very much. The sample 1 (F_1) macarons received scores of 9, 9, 8, and 9 for appearance, color, texture, and flavor. A remarkable 8.5 hedonic ratings were given to sample 1 for overall acceptability, indicating that it is liked extremely. Ratings of 7, 6, 7, and 8 were given for the sample 2 (F_2) macarons for appearance, color, texture, and flavor. Sample 2 received 7 hedonic ratings for overall acceptability, indicating that it is liked moderately. Because of its attractive appearance, pleasant taste, appealing texture, eye catching color, and overall acceptability, Sample 1 (F_1) received a rating of liked extremely. As a result, vegan, gluten-free macarons made with the F_1 formulation were chosen as the best macarons.

4. Conclusion

The main objective of this research is to develop nutritious, attractive and cost-effective, vegan and gluten-free macarons based on jackfruit and wheatgrass, which are locally available in easily cultivated regions around the world, and their sensory benefits. This paper reports the nutritional value of a sample of jackfruit as a staple food based on amino acids, fatty acids, and carbohydrates. Jackfruit can replace the function of wheat flour as a raw material for the production of processed foods. Sample 1 (F_1) was determined to have the best vegan, gluten-free macaron formulation. According to the aforementioned results, sample 1 formulation has 385.75 KCal of energy, 0.27 g of fat, 0.27 g of protein, 95.56 g of carbohydrates, 2.8% moisture, and 1.10 g of total ash. However, choosing an ideal egg substitute at the optimal use concentration for bakery products requires extensive research and development studies. It is recognized that aquafaba has good potential to enter the egg substitute market. Therefore, further studies are needed to evaluate the effects of using aquafaba derived from different beans in eggless breadfruit macarons production and also for optimization conditions for soaking and cooking aquafaba.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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