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Effect of Oats and Millet composition in Gluten-free Nutrient wafer

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Authors' contributions

This work was carried out in collaboration among all authors. Author SC developed the idea of this work, supervised the study, standardized the process and drafted the manuscript. Author SK wrote and reviewed the manuscript and did administrative support and some part of the work. Author RR was responsible for doing the part of work under the supervision of author SC. All authors read and approved the final manuscript.

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ABSTRACT

Pearl Millet [*Pennisetum glaucum* (L.)] is a widely cultivated staple crop and nutritionally rich cereal grain. The cultivar can tolerate drought and high temperatures, making it suitable for arid and semi-arid regions, especially in Africa and Asia.

Millet-based products have numerous health benefits like lowering cholesterol, managing blood sugar, and many others. It is rich in antioxidants, fiber, and various micronutrients. Millet is gluten-free, suitable alternative for individuals with gluten intolerance or celiac disease.

Methods: Low-sugar-gluten-free Pearl millet wafer is a low-moisture baked food prepared from a mixed batter of millet powder, and oats. A waffle iron toaster (1000W) is used to prepare the wafer The nutritional components were analyzed and calorie calculation was done following the Atwater system. The total energy from a 100 gm wafer serving was found to be around 289 calories.

Results and Discussions: The product was typically shaped in a square-grooved sheet, with a density around 0.2gm/cc, the matrix is aerated and fluffy. Total final moisture, ash and extracted fat

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content was also estimated. The average thickness of the wafer was around 5mm. Sensory parameters like crispiness, chewiness and mouthfeel were evaluated on a hedonic scale while the crispiness is correlated to the final moisture content.
Product cost was calculated including the energy cost calculation. The cost of the final product was Rs 45/100gm which is at per the marketed wafers.
Conclusion: The improved quality was targeted to achieve in a model of low-emission process to reduce the energy cost and increase production efficiency with better nutritional component retention.

Keywords: Gluten free; Nutri-wafer; pearl millet; low cost; energy efficient.

1. INTRODUCTION

Millet (Pearl Millet ; *Pennisetum glaucum* (L.)) is an important cultivar especially in Africa and Asia. It has many beneficial health effect. It is rich in dietary fibres and cholesterol-lowering properties, so effective for heart patients. It is quite a perfect diet supplement for patients with Celiac disease and gluten intolerance as it is gluten-free and easily digested. It acts as a therapeutic agent for people with frequent acidity and stomach ulcers. It is rich in fiber and prevents constipation helping to promote healthy gut [1]. Millet provides enough protein so vegetarians might get the required protein from millets even if they do not consume meat and fish products. This is where pearl millets can take the role to compensate protein requirements. Further, it lowers blood pressure as it is rich in potassium. The mineral composition of millet gives the privilege to make bone stronger. The cause is high phosphorus content of millet. Millets are rich in antioxidants prevent early ageing, cardiovascular diseases, and helps in faster wound healing. It is ideal for weight management and reduce obesity [2,3].

Gluten free nutriwafer is known to have many health benefits, and have been accepted by the public as balanced wafer formulation with a high content of antioxidants. The purpose of gluten free nutrient wafer is to provide people vitamins, energy etc. [4].

One good feature of nutri-wafer is that they can be conveniently eaten anytime before, during, or after an activity. The daily snack Nutri-wafer are easy to carry and readily available. The high demand for gluten-free nutri-wafers can satisfy the nutritional requirements of chronic celiac individuals also. It is rich in minerals and the Gluten-free products are also digested easily. It act as therapeutic agents for people with stomach ulcers and frequent problem of acidity. It is rich in fiber and prevents constipation helping to promote healthy gut [1].

Millet is a good protein source for vegetarians, cannot get the needed protein from meat and fish or meat products. This is where pearl millets can take the role to compensate, [2,3]. Further, Gluten free nutri-wafer is known to have many health benefits, and have better acceptability in the public as a gluten-free free nutritionally balanced product [4]. The purpose of gluten free nutrient wafer is to provide people energy, enough micronutrients and prebiotic fiber [5].

Gluten-free cereals also have lesser fat content [6]. Several studies have shown that obesity and weight gain are common problems among those who consume food with a lower net protein content, including those with celiac disease [7]. Gluten-containing products are sometimes detrimental for people who have celiac disease or non celiac gluten sensitivity [8,9]. Thus, the objective of the current work is to develop a gluten-free nutritient rich wafer formulation with a high fiber content.

2. MATERIALS AND METHODS

2.1 Preparation of Wafer

Following are the detailed steps of preparation of nutri wafer

2.1.1 Batter preparation

Millet flour, floured oats, milk powder, Sugar powder or honey and water mixed for 15 minutes to achieve a homogeneous batter using a high-shear mixer (Three compositions of wafer A, B, C Ref. Table 1). It is best suited because the slower mixers may allow formation of gluten lump and strands [10]. The suspension in cold water normally reduces the tendency of gluten lump formation. Immediately after mixing, the batter is mechanically beaten for air incorporation and kept it at room temperature avoiding high-temperature zones for settling.

2.1.2 Baking

The batter is set on a waffle machine to start the baking process. The baking is done in batch mode in the Wafer plate heating ovens. These ovens are made up of metal plates with side hinges, typically thin and usually bear smooth perforated surface patterns. The surface acts as heating surface as the metal on the surface has a very high heat transfer coefficient. The equipment runs with the consumption of electrical energy individually by 1000KWH. Electric coils and heating arrangement was at the lower side of the stack of plates. The batter is poured, in an array, across the lower plate, and on closing and locking with the upper plate, it rapidly produces steam that spreads over the batter evenly throughout the gap between the array of plates and the cover. It helps in the cooking and baking of the batter into a crisp form [11]. Some of the steam and heat was also venting out through the vents. The thickness of the wafers is proportional to the gap between the two plates.

2.1.3 Cooling cutting and wrapping

The wafers are cooled to 10-12^{o}C using convective dry air circulation. The Relative Humidity (RH) of the air in the working chamber was kept as low as possible in the range of 15%$\pm$2% to avoid further moisture uptake by the exposed wafers during cooling [12]. After heat release immediately the waters were wrapped.

2.2 Shelf Life Study of the Wafers

The wafers were preserved in HDPE ziplock packaging material for three months at 25^{o}C with 5% RH inside and 50% RH outside the pack. All the physicochemical and microbial analyses were performed with the preserved sample to estimate the shelf life. Sensory analysis was also performed just after preparation and 3 months later with the preserved product and the data was reported in 9 point hedonic scale with the average score of 25 panelists. The sensory analysis was performed in a separate sensory panel room [13].

2.3 Physical and Chemical Analysis of Wafer

Detailed analysis are given in the following paragraphs

2.4 Specific Gravity and Viscosity

Prior to baking specific gravity of the batter was measured with standard procedure and viscosity of the batter was measured using the falling sphere method following Stoke's law. The samples were analysed in triplicate. Bulk density was measured using the dried and cooled wafer [14].

2.5 Thickness and Texture Analysis

Thickness was measured using Vernier sliding calipers for all the three (A,B,C) types of wafers. Mechanical properties of the wafers were investigated by using an automated Texture Analyzer (Brookfield, Middleboro, MA) Peak stress require to overcome the give Hardness/firmness was evaluated using compression force. Compression and fracturability tests were performed on wafer samples using a cylindrical probe Texture analyser (Microsystems) at a test speed of 1 mm/s. The load was calculated in terms of Newton (N) and correlated with the breakability by teeth and chewability. It was also correlated to the strength of the wafer texture to withstand any external mechanical force during carriage in the packaged form. The study was done with three or more samples for each of the cases. Most significant data (Pvalue $\leq$ 0.05)and their average value was taken using standard statistical software [15].

2.6 Proximate Analysis

Moisture analysis was done in the Hot Air oven (SSU/Biolabs) with constant heating of 4.5 hrs. at 105^{o}C. Fat estimation of the final product was done by Soxhlet extraction method. Total protein was measured using Kjeldahl method. Total reducing sugar was measured by Fehling's method. The final moisture content was measured on both dry basis and wet basis. Crude fiber was detected by gravimetric method following acid and alkaline digestion. The moisture analysis was also done for the sample preserved for three months. The ash or total mineral content was measured by muffle furnace at 550^{o}C for 24 hrs [16].

2.7 Nutritional Analysis

Nutritional analysis of the final product was done using the Atwater system measuring the total nutritional components (protein, fat and carbohydrate) and their calorific contribution. Considering 4 Kcal /Kg of carbohydrate or Protein and 9 kcal/ Kg of the total nutritional composition for fat components. The nutritional score was assessed using the above-mentioned method [17].

2.8 Microbial Analysis

The preserved samples were tested for microbial safety specifically for yeast and mold infection. Both vegetative and spore forms were tested by microscopic examination. The tests were conducted for dry wafer and the value expressed in cfu/gm of the food item (wafer) for each type (A,B,C) after preservation [18].

2.9 Sensory Analyses

Through sensory analysis, characteristics like texture, flavor, taste, appearance, smell of the wafers were measured from the panelists. Panelists (twenty five in numbers) were allowed to sit in a panelist's room and scored in a double blinded way. The test is performed for purpose of accepting or rejecting food products using 9-point hedonic scale.

2.10 Market Survey of Gluten Based Nutri-wafer

A market survey was performed in the local area, nearby rural, few urban and semiurban areas of West Bengal where rice, wheat and potato-based products are more popular. A questionnaire was given to the common consumers to determine their level of acceptability of the millet Nutri-wafer. At the time of the survey the consumers were allowed to taste the product if they liked to. From this data the potentiality of market acceptance of the product was estimated. A detailed cost analysis was also performed with the millet-based Nutri-wafer to support its market potential [19,20].

3. RESULTS AND DISCUSSION

The results obtained from the work on development of wafers supplemented with pearl millet flour and oats flour in different ratios are presented in this work. The results of this study are tabulated and discussed keeping in view the various objectives of the study.

3.1 Textural Properties of Wafers

Physical analyses show that it has a thickness range of 5 mm, bulk density around 0.2 gm / cc and for crushing it requires 0.8-1.5 N of mechanical force. Type C requires force around 0.8 N and Type A requires force around 1.5 N. While Type B requires force around 1.1 N as observed in Texture analyser. The values may be correlated to the variations in millet and oats content. Higher the oats content lesser is the force required probably due to more fiber content.

3.2 Proximate Analysis of Wafer Formulations (A, B, C)

3.2.1 Moisture content

The three formulations of wafer, A,B, and C showed a very mild variation in the moisture contents. It could be due to the difference in the quantity of water used for batter and by the influence of increasing percentage of the content of pearl millet flour. Moisture Content was highest in sample formulation A (60% pearl millet flour) with7.5% moisture value. The moisture content was found to increase by 1-2% in 3 months preserved wafer.

3.2.2 Protein content

The protein content is contributed mainly by millet flour as well as by oats. The protein content was highest (12%) in sample A due to the highest pearl millet flour content in the composition.

3.2.3 Carbohydates

The carbohydrate content was found to be the highest (69 - 70 %) in formulations A and B. It could be due to the increased content of the pearl millet flour and added oats. Both are rich in carbohydrates.

Table 1. Table of composition of the wafers

	Optimised formulation A for Single layer % of total weight	**Optimised formulation B % of total weight**	**Optimised formulation C % of total weight**	**Time of heating**	**Wattage** KWH
Pearl Millet	60	50	40	30 minutes	1000
Oats	20	30	40		
Sugar / Honey	7	7	7		
Butter/ Refined oil	10	10	10		
Water	As required for batter preparation	As required for batter preparation	As required for batter preparation		
Milk Powder /peanut (Optional)	3	3	3		

Table 2. Table for sensory analysis of the wafers

	Sensory score (Average of 25 panellists) 0-9 Hedonic scale					
Sensory Profile	**Wafer Composition A (Before Preservation)**	**Wafer Composition A (After Preservation)**	**Wafer Composition B (Before Preservation)**	**Wafer Composition B (After Preservation)**	**Wafer Composition C (Before Preservation)**	**Wafer Composition C (After Preservation)**
Colour	9	9	9	9	9	9
Crispiness	9	8	9	8	9	9
Flavour	8	8	8	7	8	7
Surface Texture	8	8	8	8	8	8
Mouthfeel	8	7	8	7	8	7
Overall appearance	7	7	8	7	7	7

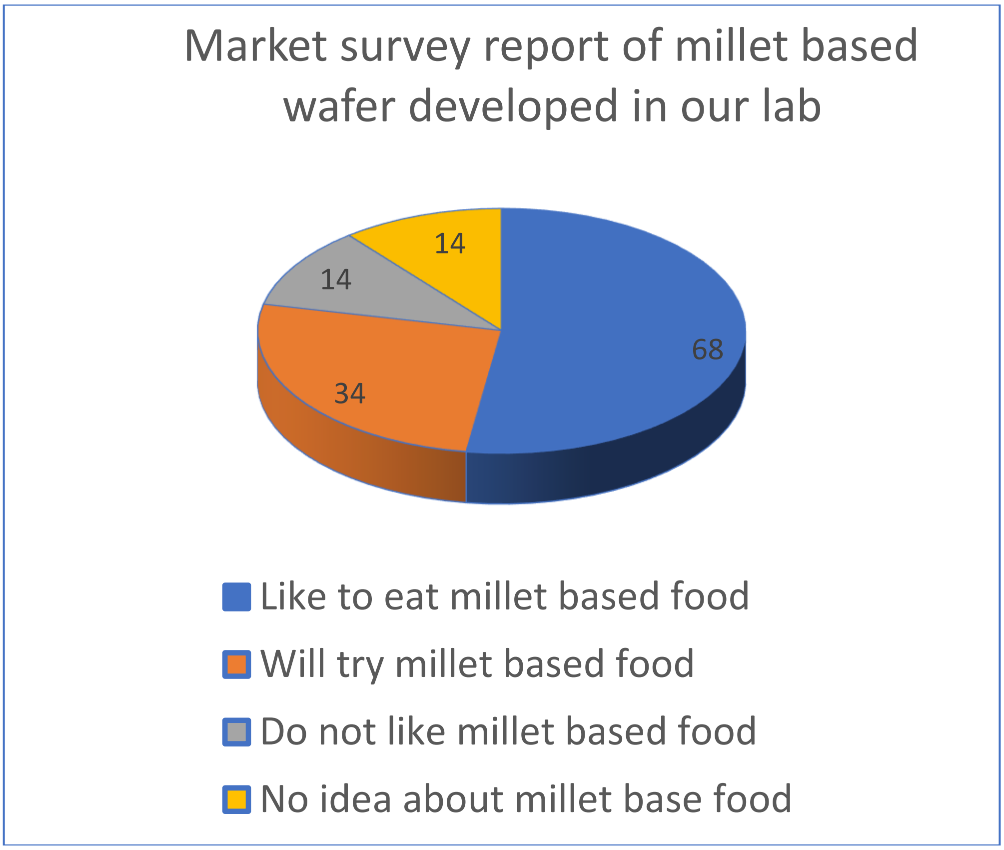

Fig. 1. Market Survey Report of Millet based Nutri-Wafer

3.2.4 Fat content

The fat content was almost similar in samples A, B, C.

3.2.5 Ash Content

The mineral content was found to be highest (1.6%) in sample A followed by sample B. It could be due to higher percentage of millet.

3.2.6 Crude fiber

Fiber content increased in the order of A<B<C due to oats and pearl millet flour composition. Crude fiber content is highest (5.6 %) in the formulation C with 40 % pearl millet flour and 40 % oats followed by formulation B with 30% oats flour and 50 % pearl millet and so on.

3.3 Microbial Analysis

Microbial analyses of various wafers formulations A, B, and C was done mainly tested for any Fungal growth on storage in terms of CFU/gm. Any considerable increase in bacterial or fungal count was not observed. The range of microbial count found from hemocytometer counting is within 10-100 CFU / gm of the wafer even in the preserved one.

3.4 Nutrirional Analysis

The nutri-wafer found to be healthy nutrition rich food. Nutritional analysis with the following level of calorie score are given below.

Composition A

Calorie from

1. Total fat-100 Cal / 100 gm of
2. Total protein 25 cal / 100 gm
3. Total carbohydrate-282 cal /100 gm

Composition B

Calories from

1. Total fat-100 Cal / 100 gm
2. Total protein -23.25 cal / 100 gm
3. Total carbohydrate-270 cal/ 100 gm

(Fiber content increased due to contribution from oats)

Composition C

Calorie from

1. Total fat-100cal / 100 gm
2. Total protein -21 cal/100 gm
3. Total carbohydrate-260cal/100 gm
4. (Fiber content increased due to contribution from oats)

3.5 Cost Calculation for Wafer

For cost calculation total Material cost and Energy Cost was considered in actuation. But for scaleup and industrial implementation the cost calculation included the raw material energy, labour, establishment costs. The total actual cost for our production came to be Rs 40-42 per 100 gm, while on scale up and large scale production it came around Rs. 45-48 per 100 gm which is at per the market cost of existing wafers depending on the compositions.

3.6 Sensory Analysis

Sensory Characteristics of wafers incorporated with pearl millet flour and oats flour The three formulations were subjected to sensory evaluation. The sensory scores suggested that composition B (50 % pearl millet flour + 30 % oats flour) had highest acceptability for mainly for the textural characteristics crispiness, colour and flavour. Nutritionally and organoleptically (Taste) the other formulations were also effective but their visual appearance was negatively affected due to increased intensity of Color compared to the control. (Table 2) Averaging the value of 25 panelists.

3.7 Market Potential Analysis of Gluten based Nutri- wafer

It was observed that about 68 % of the consumers gave their opinion came up with the acceptability of the product. About 14 % have no idea about the millet based food or wafers, so people needs to get trained further and know the values of consumption of millet based wafers. (Fig. 1). The cost was even lower than the currently marketed products.

4. CONCLUSION

Millets based wafer developed in this work is a nutrient dense, gluten free alternative to traditional grains that can have a variety of health benefits. They are a great source of protein, minerals and dietary fiber. Also, millets are less expensive and functionally unique from traditional grains for its gluten free properties [19,20].

The product Nutri-wafer contains oats, honey peanut and butter which have been included for value addition. Honey is a source of antioxidants, Anti-inflammatory and immunity-boosting components. It Improves lipid (fat) metabolism [21,22]. It is rich in vitamins and minerals, promotes healthy gut bacteria and improves digestion, making it helpful in managing gastrointestinal issues like ulcers and gastroenteritis. It is a good source of carbohydrates, hence, it can be used as pre and post-workout food. Millet is a beneficial component of a diabetic diet. Pearl millets contain resistant starches and fibrous oligosaccharides that are digested slowly and maintain a stable glycemic condition. Thus it is a healthy food option for diabetics. The soluble oat fiber contains beta-glucans [6]. They helps in lowering blood cholesterol. Important phytochemicals present in oats also help in lowering the chances of contracting many chronic diseases and cancer. Daily consumption of Millet and oats also contributes to reducing high blood pressure. As a result routine consumption can reduce the need for antihypertensive and antidiabetic medications. Millets and oats can also contribute to major nutrition and calories. Components of Oats can control many metabolic pathway components resulting in improved health [7,10].

However, it is not only the sensory properties are the only determinant of consumer acceptance. Social and environmental factors, nutritional knowledge, the likeliness of specific food, choice and preference of products, food habits, packaging, etc., have a great influence on the success of a product in the market. For these reasons, sensory analysis, along with consumer research, is required to be done by the industries for commercialization. Simultaneously quality improvement and constant innovations need to be an integral part of it [2,8,12,13], which helps to better elucidate the innovative technologies and their implementation at stages of new product development.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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