PROCESS OPTIMIZATION FOR DEVELOPMENT OF EDIBLE PLATES USING BY-PRODUCTS OF RICE AND DHAL PROCESSING INDUSTRIES

Abstract: Edible plates can be used as utensils to serve solids, semi-solids and highly viscous liquid food products whichare made out of food grains and are filled with various nutrients without any added preservatives.Edible plates from the rice bran flour (RBF), pigeonpeabrokens flour (PBF)and wheat flour (WF) were prepared by mixing in different proportions *viz*., 10, 15 and 20% of RBF, 20, 25 and 30% of PBF and the remaining proportion WF as the base material. Objective of this work is to evaluate the quality characteristics of developed edible plates. The optimized treatment was obtained with 20% of RBF, 30% of PBF and WF of 50%. The hardness and fracturability of the was found to be maximum (25.46 and 12.79 N)in T_9. The tensile strength and elongation at break was also more in treatment T_9 of 3.36 MPa and 2.13%. The tensile strength and elongation at break increased with the increase in supplementation level of by-products.
Keywords: Edible plates, composite flour, rice bran flour, fracturability, hardness

1. INTRODUCTION

India is one of the largest producer of food grains and stands among top three in terms of production of various agricultural commodities like paddy, wheat, pulses, groundnut, rapeseeds, fruits, vegetables, sugarcane, tea, jute, cotton, tobacco leaves, *etc*. The total food grain production in India is estimated as 283.37 million tonnes during the year 2018-19 as compared to 277.49 million tonnes in the previous year. Among the food grains, the production of cereals account for 260.15 million tonnes. The production of rice, wheat and pulses were 115.6, 99.12 and 24.02 million tonnes, respectively during 2018-19 (Anon., 2019).

In India, rice is being processed in well established rice milling industries. The major by-products of rice milling industry are rice husk (20-22%) and rice bran (8-10%). Rice bran is a good source of proteins, minerals, fibre and fatty acids. Rice bran proteins are rich in essential amino acids specially lysine (Gul *et al*., 2015). In rice bran, plenty of other nutrients and active compositions, such as non-starch polysaccharides, phenolic acids, flavonoids, tocopherols, tocotrienols, c-oryzanol and phytic acid (Goufo and Trindade, 2014).Baked products such as cookies, muffins, pastries have all shown a better nutritional value with the use of rice bran flour (Alauddina *et al*., 2017).Pigeonpea is the second largest pulse crop accounting for about 20% of total pulse production in India. During the processes of dhal milling, the losses due to powder and broken are estimated to be about 10-15%. The broken dhal has got very less commercial value in the market. These broken dhal have a good potential for usage in the preparation of different value added products (Anon., 2016).With increased urbanization, most of the people are stepping out for jobs, they are having hardly any time for cooking and washing utensils. In fast food restaurants, canteens, town festivals, sport events and feasts, *etc*., disposable tableware is distributed to the restaurant guests in place of traditional durable tableware in order to simplify management and avoid washing-up (Patil and Sinhal, 2018).

Utensils used in our routine life are cups, bowls, cutleries, bottles, *etc*. Generally, utensils and cutleries are made of silver, steel, aluminum, brass, copper or any other alloy, wood or plastics, *etc*. Plastic waste is dangerous to the human health as it contains several hazardous chemical complexes and carcinogens that may leach into the food (Gautham and Caetano, 2017). Therefore, there is always a need for an alternative to these plastic cutleries. Biodegradable and edible cutleries are eco-friendly and also easily disposable. Biodegradable cutleries are made from different sustainable resources like plant based materials like banana, areca, tapioca, sugarcane bagasse, *etc*. The biodegradable articles inventions are largely based on injection or extrusion methods of production, which are energy intensive processes. To overcome the difficulties in the production of biodegradable cutleries, there is a need to search for an alternative processes or products (Anu *et al*., 2012).

One of the possible way to utilise the broken dhal and rice bran could be in the preparation of edible cutleries to enhance its nutritional value. Edible cutleries have created a storm interest in various countries to adopt smarter, safer and cleaner substitutes for single use plastic and biodegradable cutleries (Rashid, 2019). Edible cutleries can be used as utensils to serve solids, semi-solids and highly viscous liquid food products (Woods and Martel, 2002). Generally, the edible cutleries are made of food grains and are filled with various nutrients without any added preservatives. These are environment friendly which can be discarded and decomposed easily (Anu *et al*., 2012).

2. MATERIALS AND METHODS

The raw materials *viz.*, rice bran and pigeonpea brokens were procured from local rice and dhal mill. Wheat flour was procured from the local market. These selected by-products were cleaned and ground to fine powder. The flour samples were passed through the sieve No. 170 and obtained particle size of 88-90 µm (Ahmed *et al*., 2016).

Quality parameters of developed edible plates

The composite flour for the development of edible plates were prepared by mixing rice bran flour (10, 15, 20%), pigeonpeabrokens flour (20, 25, 30%) and wheat flour as the base material. The treatment details are shown in Table 1. The process flow chart for the development of edible plates is shown in Fig. 1. Guar gum powder and water were added to the flour mixture. A chapathi making roller was used to knead the dough (60 g).The kneaded dough was placed in the plate mould and baked for 15 minutes in the deck oven at 180±5°C.The edible plate made from only wheat flour was considered as control. The prepared edible plate were cooled to a room temperature (30±2°C) and packed in polyethylene bag until further analysis.

Table 1. Treatment combinations of composite flour with selected proportions of rice bran flour (RBF), pigeonpeabrokens flour (PBF) and wheat flour (WF)

Treatment	Details of the treatment
T_0	100% WF
T_1	10% RBF + 20% PBF + 70% WF
T_2	10% RBF + 25% PBF + 65% WF
T_3	10% RBF + 30% PBF + 60% WF
T_4	15% RBF + 20% PBF + 65% WF
T_5	15% RBF + 25% PBF + 60% WF
T_6	15% RBF + 30% PBF + 55% WF
T_7	20% RBF + 20% PBF + 60% WF
T_8	20% RBF + 25% PBF + 55% WF
T_9	20% RBF + 30% PBF + 50% WF

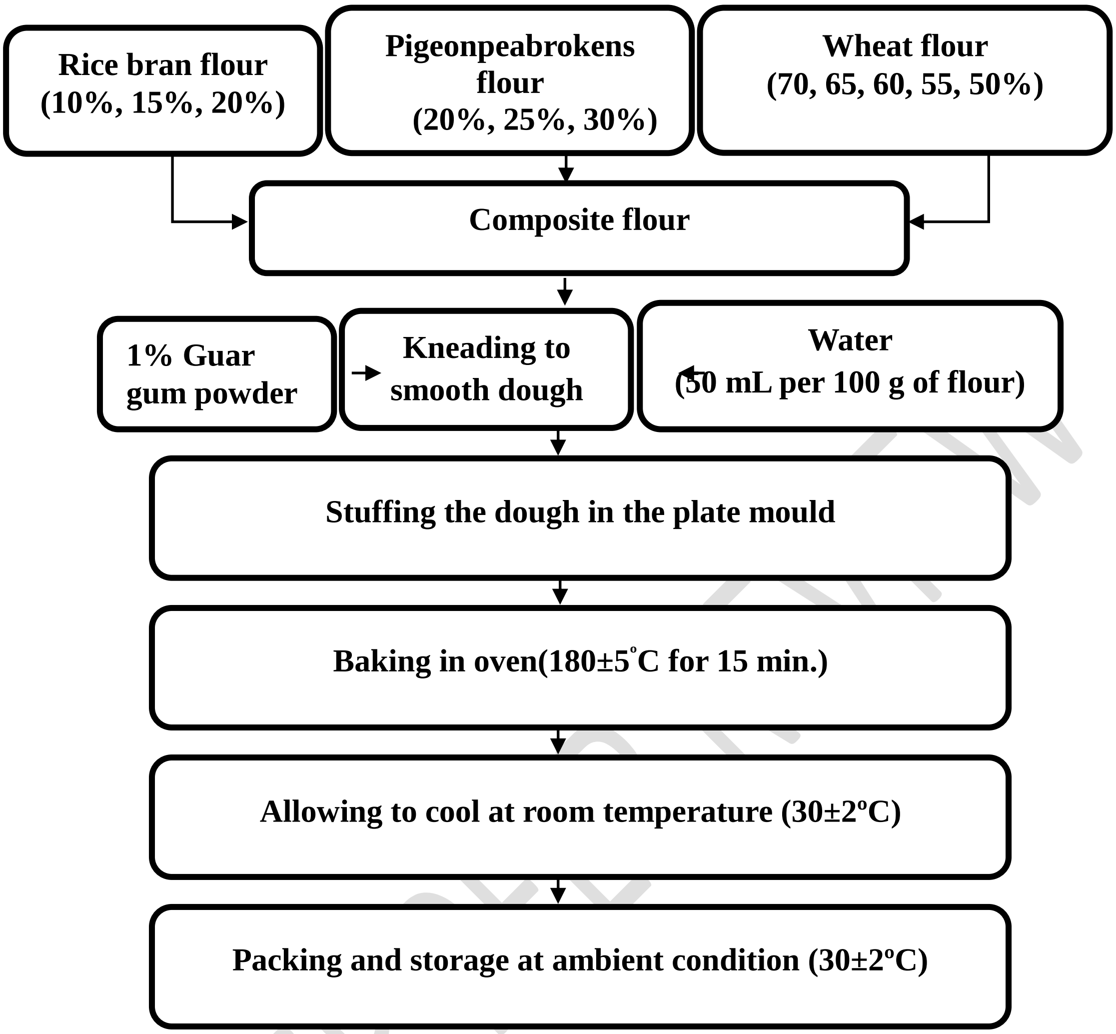

Fig. 1. Process flow chart for the development of edible plates

Texture profile analysis (TPA)

Textural qualities of edible plateswere measured with this device Textural Analyzer (M/s. Stable Micro Systems, TA.XT Plus/TA.HD, Vienna court, UK).The texture analyzer (TA) was a microprocessor controlled analysis system, which could be interfaced to a wide range of peripherals, including PC-type computers. The texture analyzer measured force, distance, and time in a most basic test, thus providing three dimensional product analysis. Forces could be measured against set distances and distances may be measured to achieve set forces. The probe carrier contained a very sensitive load cell. The TA.HD plus load cell had electronic overload protection. The TA-XT plus load cell had mechanical overload. The analyzer was linked to a computer that recorded the data via software program Stable Micro System Exponents software.

The experiments were carried out by different tests that generated plot of force (g) vs. time(s), from which texture values for edible plates were obtained. Three replications of each combination were taken for analysis. During the testing, the samples were held manually against the base plate and the different tests were applied according to TA settings. The textural properties such as hardness and fracturability were measured by using compression test. The ball probe was used to measure the compression test with the pre-test speed, test speed and post-test speed of 1.0, 1.0 and 10.0 mm/s, respectively (Panghal *et al*., 2019).

Tensile strength

The tensile strength of a material is the maximum amount of tensile (pulling) stress that it can take before failure, such as breaking or permanent deformation. The tensile strength of developed edible plates was calculated. The texture analyzer (Stable micro systems, TA.XT Plus/TA.HD, Vienna court, UK) with a 5 kg load cell equipped with tensile grips was used to measure the tensile strength (TS) of developed edible plates according to ASTM D-882 standard. Edible plate sample size of 70 mm x 20 mm was used for the experiment. Grip separation was set at 50 mm, pre-test speed of 2 mm/s, test speed of 1 mm/s and post test speed of 2 mm/s with a cross-head speed of 1.00 mm/s (Barros, 2010 and Ojagh *et al*., 2010). Tensile strength of edible plateswere calculated by using the following formula.

$$\text{Tensile strength} = \frac{F}{L \times W} \quad \text{--- (3.7)}$$

Where,

TS = Tensile strength (MPa)
F = Tension at break (N)
L = Length of plate (mm)
W= Width of plate (mm)

Elongation at break

Elongation at break is the measure of materials ductility. This measurement shows how much a material can be stretched, as a percentage of its original dimensions, before it breaks. The ductility of a material depends largely on its chemical composition. Elongation at break of developed edible plateswas determined by using textural analyser. Elongation at break (E_b) of developed edible plates was calculated by using the following formula (Ojagh *et al*., 2010).

$$\text{Elongation at break}(\%) = \frac{L_b}{L_o} \times 100 \quad \text{--- (3.8)}$$

Where,

E_b = Elongation at break (%)
L_b = Length of edible plate at break (mm)
L_o = Original length of edible plate (mm)

RESULTS AND DISCUSSION

The results of hardness, fracturability, tensile strength and elongation at break are presented in Table 2.

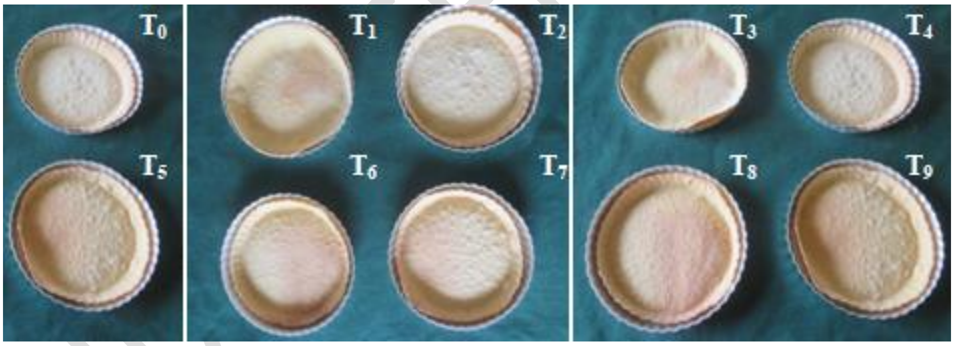

Plate 1: Developed edible plates

Textural properties of the developed edible plates and spoons

Texture Profile Analysis (TPA) was carried out for the developed edible plates. The textural properties of developed edible plates, like hardness and fracturability were analysed and are presented in Table 2.

Hardness

The texture analyser was used to determine the hardness of edible plates, and the results are shown in Table 2.The maximum hardness value of edible plate (25.46 N) was discovered in treatment T_9, whilst the minimum hardness value (23.18 N) was reported in treatment T_1.The control edible plate (T0) was determined to have a hardness of 22.87 N. This could be owing to the high fibre and protein content in the by-products flour utilised in the edible plate creation, which increased the hardness.The results are in good agreement with the findings of Bock *et al*. (2013) for bread; Jiang *et al*. (2019) for baked protein enriched corn chips.

Fracturability

Fracturability is the measure of force at which the product started to break.Table 2 displays the fracturability of the edible plates. It was discovered that the fracturability value increased from 11.08 to 12.79 N.Among the treatment combinations, the fracturability value of the edible plate was found to be maximum (12.79 N) in the treatment T_9, whereas the minimum (11.08 N) was in the treatment T_1. The fracturabilityof control edible plate (T_0) was found to be 10.57 N. It was discovered that the fracturability value improved when the percentage of by-products *viz.*, rice bran flour and pigeonpeabrokens flour increased.This could be owing to the usage of by-products with higher fibre content, which reduces the gluten content of wheat flour used in the creation of edible cutlery. Wheat flour, on average, requires less compression and penetration force than composite flour.The similar results were noticed by Divyashree *et al*. (2016) for buckwheat and chia seeds fortified biscuitsand by Gonzalez *et al.* (2018) for baked biscuits.

Tensile strength

The tensile strength of a material is the maximum amount of tensile (pulling) stress that it can take before failure, such as breaking or permanent deformation. Table 2 shows the tensile strength of the developed edible plates. The tensile strength of edible plates varied in the range from 2.95 to 3.36 MPa, according to the table.Among the different treatment, The tensile strength of edible plates was found to be highest (3.36 MPa) in treatment T_9 and lowest (2.95 MPa) in treatment T_1.The tensile strength of control edible plate (T_0) was found to be 2.87 MPa. It is evident that, as the percentage of the composition of by-products *viz.*, rice bran flour and pigeonpeabrokens flour increased, the tensile strength of the edible plate went on increasing. The results are in good agreement with the findings of Snijder *et al.* (2003) for biodegradable plates made from wheat bran and by Barros (2010) for the whole and refined wheat flour tortilla.

Elongation at break

Elongation at break is the measure of materials ductility. This measurement shows how much a material can be stretched, as a percentage of its original dimensions, before it breaks. The ductility of a material depends largely on its chemical composition. The elongation at break of the developed edible plates are presented in Table 2. Among the different treatments, the elongation at break of the developed edible plate was recorded to be maximum (2.13%) in the treatment T_9 whereas, the minimum (1.78%) was recorded in the treatment T_1. The elongation at break of control edible plate (T_0) was found to be 1.72%. This might be due to increase in the by-products used in which the composite flour is rich in fibre content. The results are in good agreement with the findings of Barros (2010) for tortilla.

Table 2. Textural properties of developed edible plates

Treatment	Hardness (N)	Fracturability (N)	Tensile strength (MPa)	Elongation at break (%)
T_0	22.87	10.57	2.87	1.72
T_1	23.18	11.08	2.95	1.78
T_2	23.52	11.29	3.21	1.81
T_3	23.97	11.41	3.22	1.82
T_4	24.05	11.62	3.25	1.83
T_5	24.27	11.85	3.27	1.87
T_6	24.58	12.16	3.28	2.02
T_7	24.97	12.34	3.33	2.05
T_8	25.13	12.58	3.35	2.09
T_9	25.46	12.79	3.36	2.13
Mean	23.35	11.77	3.21	1.91

SE(m) ±	0.232	0.259	0.073	0.043
CD @ 1 %	0.943	1.054	0.297	0.174

T_0-Control edible plates (100% WF), T_1-Edible plates (10% RBF+20% PBF + 70% WF), T_2-Edible plates(10% RBF+25% PBF + 65% WF), T_3-Edible plates(10% RBF+30% PBF+ 60% WF), T_4-Edible plates(15% RBF+20% PBF+65% WF), T_5-Edible plates(15% RBF+25% PBF + 60% WF), T_6-Edible plates(15% RBF+30% PBF+55% WF), T_7-Edible plates(20% RBF+20% PBF + 60% WF), T_8-Edible plates(20% RBF+25% PBF + 55%WF) and T_9-Edible plates(20% RBF+30% PBF + 50% WF)

CONCLUSION

The replacement of wheat flour with rice bran flour up to 20% and 30% pigeonpeabrokens flour is possible without adversely affecting sensory characteristics of edible plates. The textural properties such as hardness, fracturability, tensile strength and elongation at break was more in treatment T_9 (20% RBF+30% PBF). The textural properties increased with the increase in supplementation level of by-products.

Abbreviations:

Pigeonpeabrokens flour	PBF
Rice bran flour	RBF
Texture profile analysis	TPA
Wheat flour	WF

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 the writing or editing of this manuscript.

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