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Development and quality evaluation of nixtamalized corn tortilla chips enriched with banana and orange peel powders

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Abstract

There is increasing demand of low-cost functional foods in the market. The FAO reports that globally, half of the fruits and vegetables produced worldwide are lost or wasted due to various reasons. The present study was focused on utilization of banana peel powder and orange peel powder which provide significant health benefits environmental sustainability development of products with no. of varieties. With these issues, the study was aimed to enrich the corn tortilla chips with varied concentration (15, 20, 25 percentage) of banana peel powder and orange peel powder for enhancing nutritional value and functional properties. All these samples were organoleptically evaluated and selected the samples with good textural and sensorial characteristics for further experiments (C1, B1 and O1) the selected samples (C1, B1 and O1) were then evaluated for their proximate composition, textural properties, antioxidant activity.

Proximate analysis showed high protein content 1.52% for B1 sample (15%), 1.46% for O1 sample (15%) and high fibre content i.e., 1.20% for B1 sample (15%), 1.06% for O1 sample (15%) and antioxidant activity increased 65.2% for B1 sample (15%), 63.1% for O1 sample (15%) with an increased concentration of banana peel powder and orange peel powder. In terms of the composition and textural profile, the best possible results were achieved by samples that contain 15% banana peel powder and orange peel powder.

The most popular and economical method of extending shelf life of corn tortilla chips is to produce a product that is highly alkaline (>pH9) by the addition of hydrated lime (CaCO₃), through the process of nixtamalization. The selected samples were tested for their shelf life for a period of 30 days. The nixtamalized corn tortilla chips (C1, B1 & O1) have good stability at room temperature and shown 20 days shelf life with good sensorial and textural characteristics.

In conclusion, it has been shown that the tortilla chips enriched with banana peel powder & orange peel powder can expand the variety of available regular tortilla, producing new functional products with nixtamalization of fruit peel waste to explore the health benefits and also to reduce the fruit waste for sustainable development.

Key words: Banana peel powder, orange peel powder, Corn tortilla chips, Nixtamalization, Hydrated lime (CaCO₃), Proximate composition, Textural properties, Antioxidant activity, Organoleptic evaluation, Fiber, Protein, Shelf life.

Keywords: Banana peel powder, orange peel powder, corn tortilla chips, Nixtamalization

Introduction

Corn (*Zea mays* L.), a cereal crop belonging to the Poaceae family, is one of the world's most extensively cultivated and consumed staple foods, with major production hubs in the USA, China, Brazil, and India. Despite its versatility in food, feed, and industrial applications, corn is nutritionally limited due to its poor protein quality and deficiencies in essential nutrients like niacin, lysine, and tryptophan. However, it remains a vital source of dietary fiber, antioxidants, and energy, especially in gluten-free diets. Corn kernels consist of the pericarp, endosperm, and germ, each contributing distinct nutritional properties. Among various types, dent corn is commonly used in nixtamalization—a traditional Mesoamerican alkaline cooking process that significantly enhances corn's nutritional value and functional properties. By cooking and steeping corn in limewater, nixtamalization increases calcium and bioavailable niacin, improves dough quality, and facilitates the production of masa, the foundational ingredient for tortillas and other maize-based foods.

This ancient technique, used historically by the Aztecs, also modifies starch and protein structures, yielding improved textural and sensory qualities. Leveraging this process, the current study aims to develop and evaluate enriched tortilla chips by incorporating banana and orange peel powders, thereby enhancing nutritional value while promoting sustainable use of fruit by-products.

Banana (*Musa paradisiaca* L.), a major fruit crop of the Musaceae family, is widely cultivated in tropical and subtropical regions for its edible fruits, with a global production of approximately 116 million tonnes in 2019. Bananas are consumed in various forms—raw, cooked, dried, or processed into flour and starch—with culinary types primarily being seedless. While the fruit itself is well-utilized, the peel, often discarded as waste, holds substantial nutritional and functional potential. Banana peels are rich in dietary fiber (20-30%), proteins (6-9%), carbohydrates, and essential minerals such as phosphorus, iron, calcium, and magnesium. Importantly, banana peels exhibit high antioxidant activity due to bioactive flavonoids like catechins and epicatechins, surpassing even the pulp in antioxidant capacity. Despite this, banana peels remain underutilized, frequently contributing to environmental waste. Recent innovations have demonstrated their applicability in functional foods and value-added products, such as banana peel jam and natural antioxidants. This research leverages banana peel powder as an enriching ingredient in tortilla chips, promoting sustainability through waste valorisation and enhancing the nutritional profile of staple snack foods.

Orange peel (*Citrus sinensis* Lin) is a significant by-product generated during orange processing, with India producing around 25 lakh tonnes of oranges annually, mainly from states like Punjab, Madhya Pradesh, Andhra Pradesh, Maharashtra, Rajasthan, Assam, and Karnataka. The accumulation of orange peel waste during juice and other product manufacturing poses environmental challenges, making it essential to explore valuable applications for this resource. Rich in nutrients and bioactive compounds, orange peel contains dietary fiber, flavonoids such as hesperidin and naringin, essential oils like limonene, vitamins, and minerals. These components contribute to its antioxidant, anti-inflammatory, antimicrobial, and potential anti-carcinogenic properties. Due to its high nutritive value, orange peel holds promise for use in pharmaceutical and value-added food products, offering both health benefits and sustainable waste management solutions.

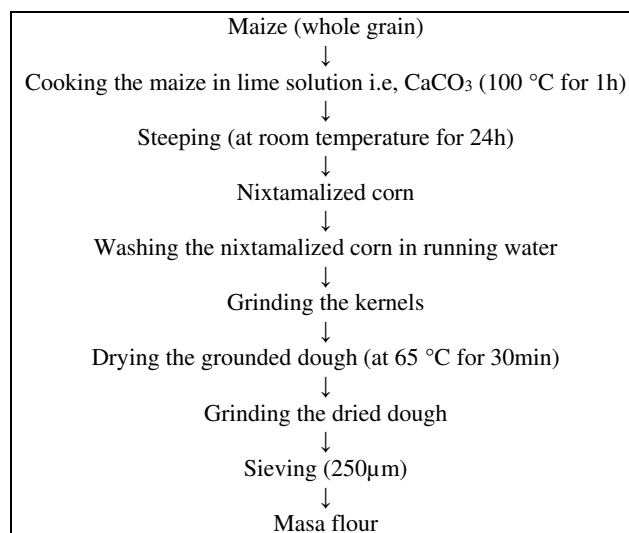
Masa flour is made by cooking corn flour in an alkaline solution, typically diluted calcium hydroxide, through a traditional process called nixtamalization, which enhances the nutritional value of corn by improving the bioavailability of nutrients like niacin and minerals while reducing antinutritional factors. Rich in carbohydrates, moderate in protein, and high in dietary fiber, masa flour supports digestive health, regulates blood sugar, and is naturally gluten-free, making it suitable for those with gluten intolerance. Widely used in Latin American cuisine, masa is the key ingredient for staple foods such as tortillas, tamales, pupusas, and sopes, demonstrating both its cultural importance and versatility in savory and sweet dishes. Its nutritional benefits, combined with its adaptability, make masa flour a valuable food product with significant health and culinary applications.

Materials and Methods

In the present study titled “Development and quality evaluation of nixtamalized corn tortilla chips enriched with banana and orange peel powders”, masa flour is rich in complex carbohydrates, calcium, dietary fiber, and certain B vitamins due to the nixtamalization process. Both banana and orange peel powders are excellent functional ingredients because of their fiber, antioxidant content, and bioactive compounds, which can improve the nutritional and functional quality of food products like tortilla chips. Proximate and nutritional analysis was carried out along with determining their physical properties. Experiments were conducted in College of Food Science and Technology, Rudrur, Nizamabad Dist.

Selection and procurement of raw materials

Raw materials used are corn kernels, banana peels, orange peels, sunflower oil, calcium carbonate and Packaging material (LDPE) are purchased from local market. Electronic weighing balance was used to determine the weight of all the ingredients. Whole maize was cooked in the lime solution i.e, CaCO_3 (100 °C for 1h), steeped at room temperature for 24 hours, nixtamalized corn, washing the nixtamalized corn under the running tap water, grinding the kernels, drying the grounded dough at 65 °C for 30 min, grinding the dried dough, sieving (250 µm), masa flour. Flow chart for preparation of powder formulation is depicted in the Fig. 1. To prepare the three different formulations, the masa flour was added in the quantities of 95, 85 and 75 g and maida added in quantities of 0, 10 and 20 g. salt was added in equal quantities in all the three formulations. Composition of 3 different formulations is given in the Table 1.



Flowchart 1: Preparation of masa flour

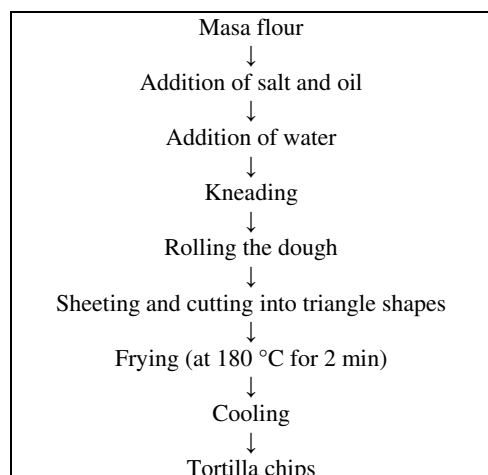
Table 1: Formulation for control sample (100 g)

Ingredients	C ₁	C ₂	C ₃
Masa flour	95 g	85 g	75 g
Salt	5 g	5 g	5 g
Maida	0 g	10 g	20 g

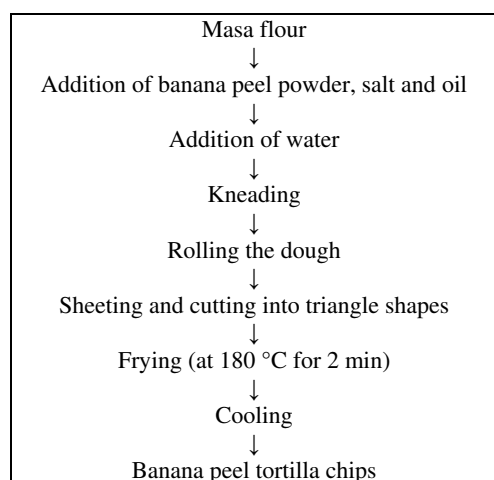
The tortilla chip samples are formulated as C₁, C₂, C₃ with different proportion. To know the acceptability, the organoleptic evaluation was conducted for these 3 samples. Among all, the semi-trained panel selected the “C₁”, which

has good sensorial characteristics. The 'C₁' sample was selected as control for further studies.

Preparation of Tortilla Chips



Preparation of banana peel powder: The selected nutritionally rich ingredients bananas procured from the local market. Bananas were peeled and cut them into small pieces, treated with 0.5% solution of citric acid for 10 mins, peels were drained and kept in tray drier, dry them for 8hrs at 65 °C, collect the dried peels, grinding and sieving (250µm), pack in air tight container. The enrichment of banana peel powder in tortilla chips given in the flowchart No.2. Composition of 3 different formulations is given in the Table 2.



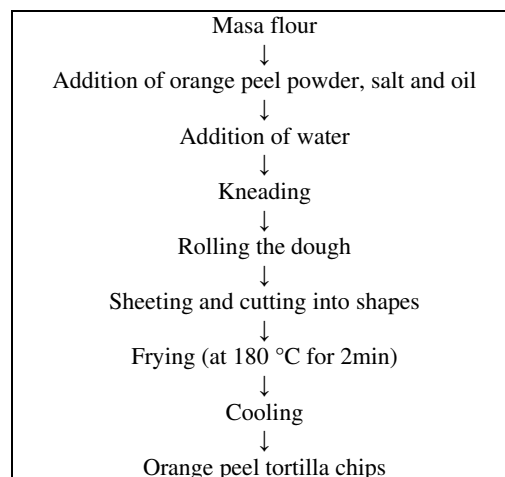
Flowchart 2: Preparation of banana peel tortilla chips

Table 2: Standardization of banana peel powder in tortilla chips (100 g)

S. No	Ingredients	Control sample	B ₁	B ₂	B ₃
1	Banana peel powder	0 g	15 g	20 g	25 g
2	Masa flour	95 g	80 g	75 g	70 g
3	Salt	5 g	5 g	5 g	5 g

Preparation of orange peel powder: Oranges were peeled and the peels were cut into small pieces, the pieces were washed, drained and kept in tray drier, dried them for 8 hrs at 65 °C. After the dried peels were collected, grinded and it was sieved by using 250µm mesh. The fine powder is packed in air tight container. The enrichment of orange peel powder in tortilla chips given in the flowchart No.3.

Composition of 3 different formulations is given in the Table 3.



Flowchart 2: Preparation of orange peel tortilla chips

Table 3: Standardization of orange peel powder in tortilla chips (100 g)

S. No	Ingredients	Control sample	O ₁	O ₂	O ₃
1	Orange peel powder	0 g	15 g	20 g	25 g
2	Masa flour	95 g	80 g	75 g	70 g
3	Salt	5 g	5 g	5 g	5 g

Analysis of selected tortilla chip samples

Nutritional composition of the major nutrients of the selected tortilla chip samples were determined by proximate analysis. Moisture content of the sample was obtained by oven drying method (AOAC, 2005). Ash content was determined using muffle furnace heated at 550 °C for 4 h and resultant ash content was calculated (AOAC, 2000). Protein content was calculated as the sum of individual amino acid residues. The procedure for estimation of protein content chosen was micro-kjeldahl method (Kirk P.L., 1950). After digestion (at 360 °C-410 °C), neutralization & distillation with 40% NaOH and 4% boric acid, titration with 0.1 N HCl was done. The percentage of nitrogen present in given formulation was calculated by the equation (1) and protein content by the equation (2).

$$\text{Nitrogen content} = \frac{(\text{Sample titrate value} - \text{blank titrate value}) \times \text{normality of HCl} \times 14 \times 100}{\text{Weight of sample} \times 1000} \quad \dots (1)$$

$$\text{Protein content (g)} = \text{Nitrogen content} \times 6.25 \quad \dots (2)$$

Fat content of the samples was measured using Soxhlet apparatus using petroleum ether and using the equation (3) (Hussain, 2023) ^[13].

$$\text{Fat content (\%)} = 100 (B-C)/A \quad \dots (3)$$

A = Formulation weight

B = Weight of the flask after extraction

C = Weight of the flask prior extraction

Estimation of fibre was done by the method involving use of boiling sulphuric acid and NaOH using the equation (4) (Madhu, *et. al.*, 2017) ^[40].

$$\text{Crude Fiber Content (\%)} = \frac{100(A-B)}{C} \dots (4)$$

Where,

A = Weight of crucible with dry residue (g)

B = Weight of crucible with ash (g)

C = Weight of formulation (g)

Carbohydrate content was estimated by difference method using the equation (5) (Menezes, *et al.*, 2004).

$$\text{Carbohydrate (\%)} = 100 - (\% \text{ Moisture} + \% \text{ Ash} + \% \text{ Fat} + \% \text{ Protein}) \dots (5)$$

Antioxidants presence was determined using DPPH method (Baliyan, *et al.*, 2022),

β-carotene (Kassaye, *et al.*, 2023) and iron content by using spectrophotometer method (Ojochegebe, *et al.*, 2023).

Texture Profile Analysis of the tortilla chips was carried out using a Texture Analyzer (e.g., TA.XTplus, Stable Micro Systems, UK) equipped with a three-point bending rig or a blade probe suitable for brittle samples. The analysis aimed to evaluate the mechanical properties associated with crispness and hardness of the tortilla chips.

The sensory evaluation of tortilla chips enriched with banana and orange peel powder were carried out by 10 semi trained panel members to know overall acceptability and for evaluation of final product. Judgements were made through rating products on a 9-point hedonic scale (Wichchukit and O'Mahony, 2015) with corresponding parameters ranging from 9 like extremely to 1 dislike extremely.

Results and Discussion

Control sample, banana peel powder tortilla chips and orange peel powder were prepared in three formulations each measuring 100 g. Proximate analysis of selected tortilla chips for moisture content, carbohydrates, protein content, crude fat, crude fibre and ash were determined and depicted in Fig 1.

It was observed from Fig. 1, the moisture content was highest in the control sample C1 (3.5%) due to greater starch gelatinization and water retention, while the lowest moisture content was recorded in the O1 sample (2.5%), likely due to the high fiber content and porosity of orange peel powder promoting faster moisture loss. The protein content was found to be lowest in the C1 sample (1.3%) since masa flour is primarily a carbohydrate source with low protein, whereas the B1 sample, incorporated with 15% banana peel powder, had the highest protein content (1.52%)

due to the concentration effect from drying and the intrinsic protein content of banana peels. Fat content was lowest in the O1 sample (11.8%), supporting findings by Zaker *et al.* (2016) [39] that orange peel powder, being high in dietary fiber, reduces fat absorption and can act as a fat replacer; the highest fat content was recorded in the C1 sample (24.4%). Carbohydrate content was highest in the control C1 sample (28.14%) due to the starch-rich nature of masa flour, while B1 had the lowest (20.25%) since banana peels are lower in starch and richer in fiber and protein; the O1 sample had slightly higher carbohydrates (21.22%) than B1, attributed to the presence of natural sugars and pectin in orange peel. The incorporation of banana peel powder notably increased the crude fiber content in B1, enhancing its dietary value, and this sample also showed the highest ash content (0.66%), reflecting its richer mineral and organic salt content.

From the Fig 2 it was observed that the hardness, gumminess, fracturability and chewiness differ significantly among three samples the hardness values of O1 sample (506 g), B1 sample (695 g) and C1 sample (420 g). B1 sample likely has a firmer structure due to banana peel powder, which may increase fiber and solid content, resulting in greater resistance to deformation. Orange peel (O1) contributes similarly but slightly less, while the control (C1) has the least fiber, leading to the lowest hardness. The gumminess was highest for C1 sample (121 g) and lowest for B1 is (32 g). The fracturability is highest in B1 sample (845 g) lowest in C1 sample (420 g). The chewiness is highest in C1 sample (66 g*mm), lowest in O1 sample. B1 high fiber and solid content from banana peel enhances its brittleness and crispness, leading to high fracturability. O1 also shows enhanced fracturability due to the presence of citrus peel fiber, but less than B1. The control sample is softer and breaks with lower force. The values of hardness and chewiness influence the acceptance of tortilla chips made with banana peel powder and orange peel powder.

It could be observed that the antioxidant activity of B1 sample has high value i.e, 65.2% among all the samples, due to their high content of phenolic compounds (flavonoids, tannins, anthocyanin) they help in neutralizing the free radicals & protect against oxidative stress. O1 sample has the (63.1%) due to the presence of flavonoids & other phytochemicals. Additionally, orange peel contains high amount of vitamin C, which is also an antioxidant. The concentration of phenolic compounds can be significantly higher in peels compared to the pulp (science direct.com). The C1 sample (45.3%) has lowest antioxidant activity, due to nixtamalization process (used to make masa) can reduce certain natural antioxidants during processing.

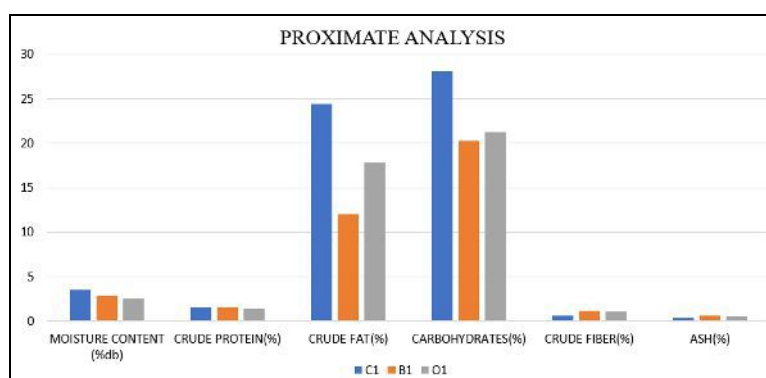


Fig 1: Proximate analysis of selected tortilla chip samples

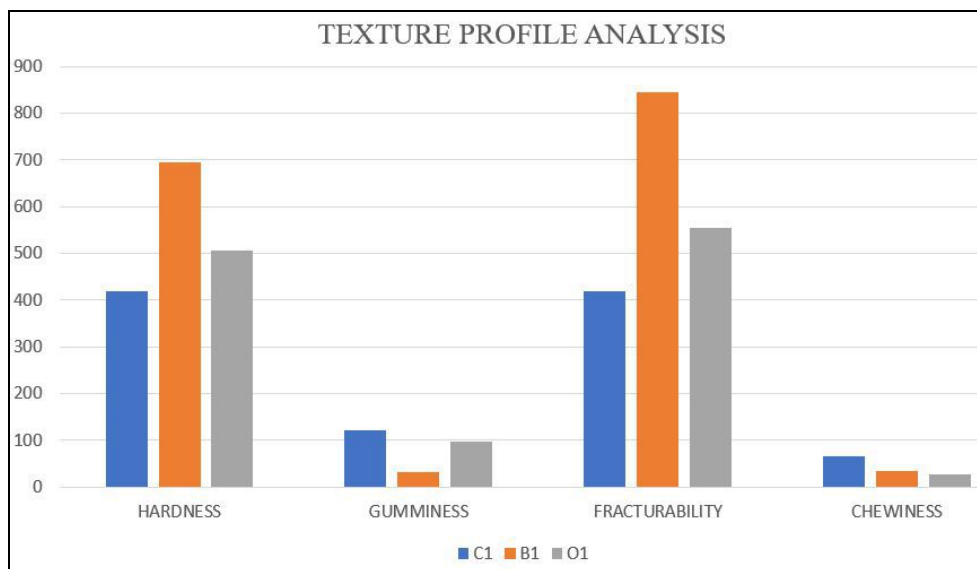


Fig 2: Texture profile analysis of selected tortilla chip samples

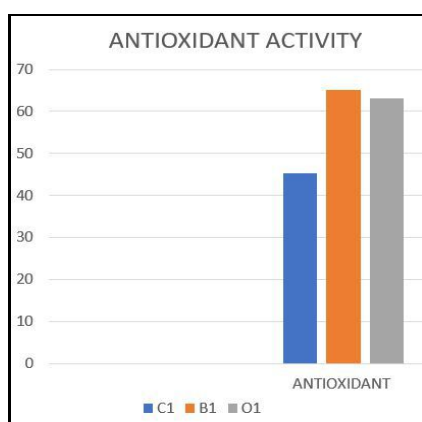


Fig 3: Antioxidant analysis of selected tortilla chip samples

Organoleptic evaluation of selected tortilla chips

From the Fig. 4, it was observed that the tortilla chips, with 0 g of maida received good acceptance, with overall acceptance score of 8.5. The individual scores for appearance, colour, taste texture, odour and flavour for C1 were 8.5, 8, 8.5, 8 and 8.5, respectively. Tortilla chips with incorporated of 15 g banana peel powder received good acceptance, with an overall acceptance score of 7.5. The individual scores for appearance, colour, taste texture, odour and flavour for B1 were 6.5, 7.5, 7, 7.5 and 7.0, respectively. Tortilla chips with incorporated of 15 g orange peel powder received good acceptance, with an overall acceptance score of 8. The individual scores for appearance, colour, taste texture, odour and flavour for O1 were 8.5, 8, 8, 8, 7.5 and 8, respectively.

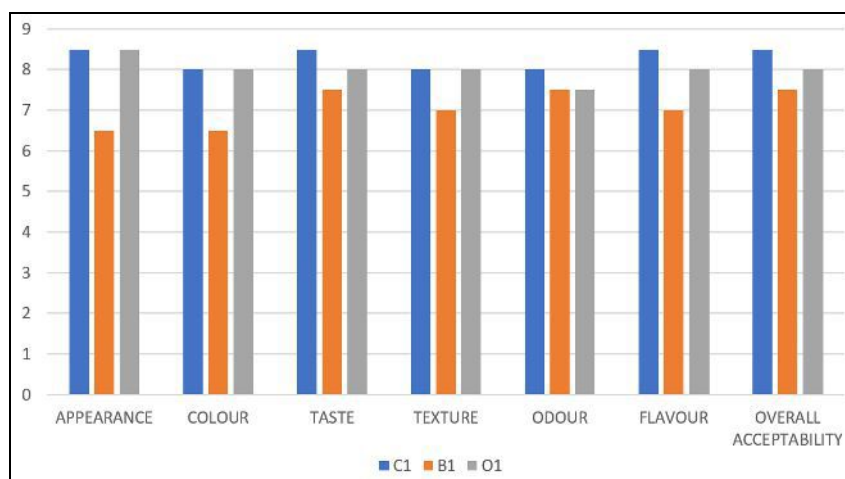


Fig 4: Sensory analysis of selected tortilla chip samples

Conclusion

The present study reports the proximate composition, textural profile, antioxidant activity and sensorial characteristics of nixtamalized corn tortilla chips enriched with varied concentrations of banana peel powder and orange peel powder. The addition of banana peel powder and orange peel powder significantly increased the nutritional value of tortilla chips i.e., protein, fibre contents compared to control sample.

The enriched tortilla chips have also reported high in antioxidant activity. According to the values obtain from instrumental analysis and sensory evaluation, the tortilla chips with 15% banana peel powder & orange peel powder increases the functional properties of tortilla chips. The nixtamalization increased the shelf life of corn tortilla chips. Further experiment is required to analyse and validate the potential health effects & to explore the benefits of fruit peel powder to reduce the wastage & promote sustainable development.

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