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Physio-chemical and Technological Evaluation of the Fruits and Vegetable Residue Flour for Biscuits and Nachos

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Abstract

The aim of the present research is an increased consumption of healthy foods to reduce chronic diseases risk is true. We formulate and standardize FVR flour from fruits & vegetables as a nutritive alternative to highly consumed snacks such as biscuits and nachos. FVR flour, multigrain atta, cornflour, chickpea flour are mixed to prepare the biscuits & nachos. They are baked.

In conclusion, nutritionally enhanced biscuits & nachos are developed from FVR flour, which provides significantly more dietary fibre and protein and less fat than traditional commercial biscuits & nachos, but with a comparable appearance and high

Acceptability: Fruits & vegetables are widely processed, and during their processing, the residue is often discarded. Some residues such as peels, seeds, have a rich composition and can be used. However, the high perishability, due to high moisture content, limits this use.

The reduction of moisture, achieved by drying, is an alternative to use these residues.

Flours made from apple, carrot, capsicum, coriander, guava, ginger, garlic, gooseberry, mint, moringa, raw papaya, spinach etc through the drying process, are evaluated for particle size distribution, structural analysis, functional group, water activity, hydrogen ionic potential, titratable acidity, total soluble solids, solubility in water and milk and water, milk absorption, to characterize them and suggest potential applications in food products. Water activity and pH values are favourable for the preservation of the flours, which also showed better solubility in water than in milk, as well as higher water uptake and milk compared to fat. These results indicated good potential for use in food processing, especially in instant products and bakery, to develop new products or replace ingredients, representing an alternative to the use of residue.

Keywords: Functional group • Physio-chemical properties • Fruit peel • TTA (total titratable acidity) • TSS (total soluble solids) • WHC (water holding capacity) • OHC (oil holding capacity) • Proximate composition • Microbial stability • Structural analysis

Objectives

To study the functional, technological and physio-chemical analysis of FVR flour.

Introduction

The food industry is responsible for generating large quantities of waste or residue. Studies have shown that about 1.3 billion tons of foods are waste worldwide per year, representing one-third of the total production of the food industry. Of this, about 0.5 billion tons are fruits & vegetables. In addition to losses in the field, great losses are observed during industrial processing [1].

In this context, there is a need to improve the full utilization of fruits & vegetables, thus minimizing the disposal and generation of residue, and enabling their use in human nutrition rather than animal feed or organic fertilization only [2,3].

The use of fruit's & vegetable processing residue as raw material for the development of new products has commercial importance, considering the interest in the sustainable development of the food industry, and the consumer awareness of the benefits of natural foods [4-6]. However, these products are susceptible to microbiological degradation, mainly due to their high water content the chemical composition, impairing their utilization [7,8]. Thus, the reduction of moisture content after drying and subsequent transformation into flour can be a viable alternative for use of these residues [9].

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Materials and Methods

In this study, the following species of fruit's were used: Apple (*Malus domestica*), Guava (*Psidium guajava*), and Raw Papaya (*Carica papaya*).

The following species of vegetables were used: Carrot (*Daucus carota*), Capsicum (*Capsiceae*), Coriander, Ginger (*Zingiber officinale*), Garlic (*Allium sativum*), Gooseberry (*Ribes uva-crispa*), Mint (*Mentha s.p.*), Moringa (*Moringa oleifera*), Spinach (*Spinacia oleracea*).

Tools & Technologies

Tools: Dehydrator, Solar dryer, Hot-air Oven, Centrifuge machine, Laminar Air Flow, Incubator Fridge, Oven, Weighing machine, measuring cup. Rolling pin, Whisker, Sieve, Knife etc.

Technologies: XRD, FTIR, Nano zeta sizer nsz 90.

Methods

The fruits & vegetables were selected for the absence of defects, washed with mild soap and running water, sanitized with sodium hypochlorite solution 100 mL.L^{-1} for 15 minutes, and drained. Then, they were peeled manually with a knife (peels+residual pulp) were packed in low-density polythene bags and subjected to drying and physicochemical characterization.

Oven-drying was a simple method to dry food using moderate temperatures, below 65°c, with no changes in the functional properties and nutritional content of fruit's & vegetables. After drying, the residue was ground in a food processor machine and sieve, resulting in vegetable residual flour (VR Flour) & fruit's residual flour (FR Flour).

Functional and physio-chemical analysis of fvr flour

Particle size: Simultaneously measures particle size and zeta potential without sample dilution the pretend Nano Zetasizer zs 90 combines the Zeta- APS and Zeta Acoustic has proven technologies into a single powerful instrument that also simultaneously analyzes per cent (%) solids, longitudinal viscosity, pH, conductivity, temperature and attenuation spectra, automated titration capability allows measurement of reagent effect on particle size, as well as, IEP determination surfactant/dispersant effects, and many others measurements (Tables 1 & 2).

Water activity

The water activity of flours was determined at 30°C using Resistive electrolytic hygrometers. The amount of water was determined by subtracting the dry weight from the initial weight, and the moisture content was then calculated as the amount of water divided by the dry weight or total weight.

Hydrogen ionic Potential (pH)

The hydrogen ionic potential (pH) were measured using a digital potentiometer calibrated with pH 4.0 and 7.0 buffer solutions, by direct immersion of the electrode into the beaker containing the sample macerated with distilled water, according to the methodology proposed by the AOAC (2012).

Total Soluble Solids (TSS)

The total soluble solids content were determined at 20°C by readings of degree Brix is a digital refractometer.

Total Titratable Acidity (TTA)

The total titratable acidity (TTA) was determined in four replicates in freshly prepared FVR flour and during its storage until 90 days. 5 g was homogenized with 30 mL of 95% ethyl alcohol and the corresponding TTA is performed by titrating against 0.1 M NaOH using a bromothymol blue indicator. The results were calculated as citric acid equivalent and are expressed as g kg^{-1} of FVR flour.

Solubility, water and oil holding capacity

The solubility, of flours for water holding (WHC) and Oil holding (OHC) Capacities were determined in four replicates based on the standard method with slight modifications. FVR flour (1g) was accurately weighed into previously tared 15 mL (Falcon tubes). Next, 10 mL of distilled water was pipetted into the tubes containing the samples. The suspensions are stirred at RT and centrifuged (1,500 x g 30 min) the supernatants were dried to a constant weight at 105°C. The residue obtained represented the number of flour granules solubilised in water (g of dry weight per 100 g of FVR, dry basis). After centrifugation, each tube is weighed then the WHC and OHC were calculated by the weight of dry solids in the supernatant expressed as a percentage of the original weight of the sample, respectively, according to Equation 1:

$$\text{Solubility} = \frac{\text{dry solids in the supernatant (g)} \times 100}{\text{Sample (g)}} \quad (1)$$

Water absorption index (WAI)

The water absorption index (WAI) of flours was determined according to adaptations by [10-12]. A suspension with 10 mL of water and 1 g flour was stirred by vortexing for 1 minute and then centrifuged at (1,500 rpm × g 30 minutes) in a centrifuge (Eppendorf tube). The supernatant was drained, and the remaining material was weighed. The difference between the sample weight before and after absorption represented the amount of absorbed water. The water absorption index was calculated according to Equation 2.

$$\frac{\text{Water absorption index(WAI)} = \text{absorbed water(g)}}{\text{Sample(g)}} \quad (2)$$

XRD (X-Ray Diffraction)

XRD was used to study the structure, composition, and physical properties of materials.

The XRD analysis of the powder samples was done in the PAN alytical Xpert Pro XRD instrument

in powder mode with the source being Cu-Kα radiation at 1.540°A. The spectra were scanned at a diffraction angle (2θ) range of 5–80 at a step size of 0.05°/step and 2 sec/step.

FTIR (Fourier Transformed Infrared)

Fourier transformed infrared spectra absorption for each sample was obtained using a Bruker Alpha Model. The samples gently mixed with micronized KBr powder and compressed into pellets at a force of 10 KN for 2 min using a manual tablet presser at room temperature. The data were recorded at room temperature in the wavelength range of 4000–500 cm−1.

Proximate composition analysis

The proximate composition of the FVR flour, biscuits and nachos were analyzed. The moisture, ash, crude fat, crude fibre and protein (N x 6.25) contents were determined according to the standard methods (AOAC 1984). Crude fibre content was determined by acid and further alkaline digestion (90°C for 1 h) on a fibre dig ester. The content of available carbohydrates was determined by the difference in the protein, fat, moisture, ash and crude fibre contents. Caloric values were computed using the water general factor system: carbohydrate (6 kcal g-1), lipid (12 kcal g^{-1}), and protein (8 kcal g^{-1}). all experiments are performed on four replicates.

Evaluation of microbiological stability

The microbial stability of FVR flour, biscuits and nachos were evaluated attending to the specifications of the international standards CODEX Alimentarius (CAC/GL 21-1997) (CAC 1997). The microbiological stability of the FVR flour, biscuits and nachos were evaluated in 12 hours, 24 hours, 72 hours by analyzing the total viable aerobic mesophilic bacteria, Escherichia coli, Bacillus cereus, Stephylo coccus aureus, yeast and mould counts and also

Table 1: Particle size of fruit's and vegetable residual flour.

Position [2θ]	Intensity (CPS)	FWHM [°]	FWHM [R]	cosθ	βcosθ	d-spacing [˚A] particle size
8.73	22.24	5.21	0.090932	0.997099	0.090668	15.29
20.73	22.68	6.52	0.113795	0.983729	0.111944	12.38

Values expressed as mean ± standard deviation, biscuit powder. Where, E8[2θ] = 5.10-5.12 and fx [cos®(d5/2)], (intensity) = 19.30-19.27.

Table 2: Functional properties of the fruit and vegetable residue (FVR) flour.

Position[2θ]	Intensity (CPS)	FWHM[°]	FWHM[R]	cosθ	βcosθ	d-spacing [˚A] particle size
7.26	30.16	3.15	0.054978	0.997994	0.054868	25.27
19.76	37.82	5.24	0.091455	0.985169	0.090099	15.38

Values expressed as mean ± standard deviation, biscuit powder. Where, H5 [2θ] = 5.08-5.10 and fx [cos®(d5/2)], (intensity) = 26.19-26.98.

the verification of the presence of Salmonella Sp, Coliforms at 35°C and 45°C. The maximum accepted levels followed the regulations of food microbiological standards. This legislation establishes microbiological standards, based on the CODEX Alimentarius, separated by category; the categories considered were fruits and vegetable products, flour and baking products.

Statistical Analysis

The experiment was carried out in a completely randomized design. The analyses were performed in triplicate, with four replications. The results were subjected to analysis of variance (ANOVA) and Fisher's test to compare means SPSS Software, using a significance level. The values were expressed as mean ± standard deviation.

Results and Discussion

Particle size

Flour particle size can vary depending on the laser diffraction method, and the scattering can detect the final quality of the manufactured products. The particle size homogeneity promotes proper and uniform cooking and prevents hardness and partial cooking, which affect the quality of the product, both in appearance and palatability [12]. Although the particle size was influenced by the laser diffraction method. it can be easily detected by the scattering step. However, [10] was emphasized that large particle size were more advantageous in maintaining the hydration and texture characteristics of the product.

Solubility, water and oil holding capacity

The water holding capacity (10 g/g flour) of FVR was higher than the oil holding capacity (1.73 g/g flour). This difference may be related to the main composition of the residue of fruits and vegetables, rich in monosaccharide and polysaccharide and their derivatives, such as pectin, which have in their chemical structure many available hydrophilic groups to connect the water molecule through H-bonds. Both, WHC and OHC were important functional properties that have been widely studied in food, as they were associated with food quality.

Another important functional property was the solubility in water. This relates to the number of soluble solids in the sample. The percentage of water solubility of FVR flour (12.7%). fruit-based flour has been appointed as suitable for incorporation in dough and pastry products due to the exhibited functional properties [9].

XRD (X-Ray Diffraction Analysis)

The present study of XRD is of great importance for the stability of powdered flour and can be determined through X-ray diffraction analysis. The presence of diffuse and large peaks in X-ray diffraction containing amorphous material is because, in the amorphous state, the molecules are disorderly displayed producing disperse bands whereas crystalline materials yield sharp and defined peaks since they are presented in a highly ordered state. The X-ray diffraction patterns of FVR flour are shown in Figures 1 & 2, respectively. The diffraction peaks observed in the graph are broad, which indicate that the crystalline size is small which was similar to the results obtained by Theivasanthi and Alagar. The particle size of each residual flour has been determined using the Debye-Scherrer formula.

$$T = \frac{K\lambda}{\beta \, COS\theta}$$

K is the shape factor, lambda is the X-ray wavelength, β is the line broadening at half the maximum intensity in radians, and θ is the Bragg angle; is the mean size of the ordered (graphite) domains, which may be smaller than or equal to the flour size. The average particle sizes were found to be 200-500nm, respectively, and were represented in Table 3. Carbon is graphite in structure and Amorphous in nature. The graphite structure can be identified at the light microscope level and through characteristic X-ray diffraction patterns. The XRD patterns of these powder give the stronger diffraction peaks at around 12, 10 and 23°. In the biscuit, the powder gives the two peak value around (8.73, 20.70). In Nachos, there were also two peaks at around 2 values at 29 and 38° of (7.26 and 19.76°) at 2θangle indicating C-material. The presence of C-group or C-type material indicates that the graphite and amorphous nature of carbon group like (fructose, glucose and sucrose) are present in the FVR flour and is not destructed after dehydration process Figure 3.

Changes in the physio-chemical properties

The acidity determination can provide important data to assess the conservation state of the product, since a decomposition process by hydrolysis or oxidation, often changes the sensory and nutritional characteristics of the product. The results of the changes in the acidity of FVR flour during its storage showed a progressive decrease in the TTA until 60 days. After 30 days, the TTA level decreased significantly by 20%.

However, no information is available in the literature concerning the evolution of TTA during storage. The importance of the TTA decrease could be related to the control of microorganism growth since these parameters were

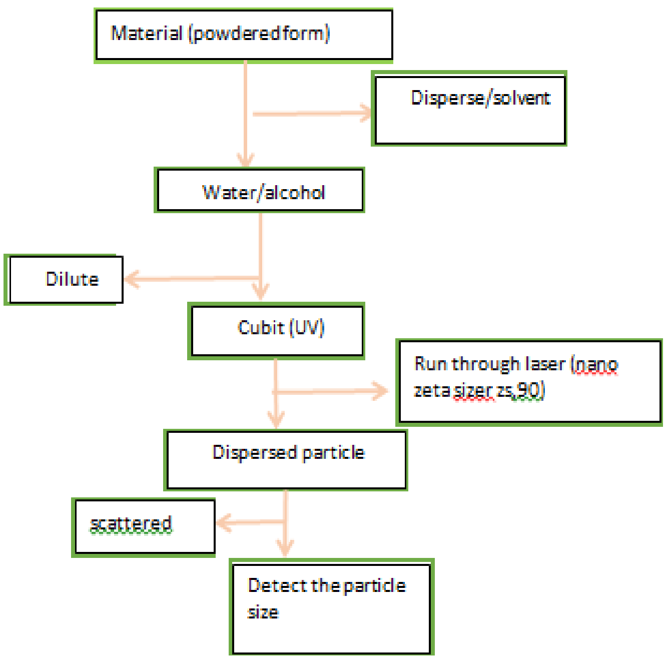

Figure 1. Support Breastfeeding.

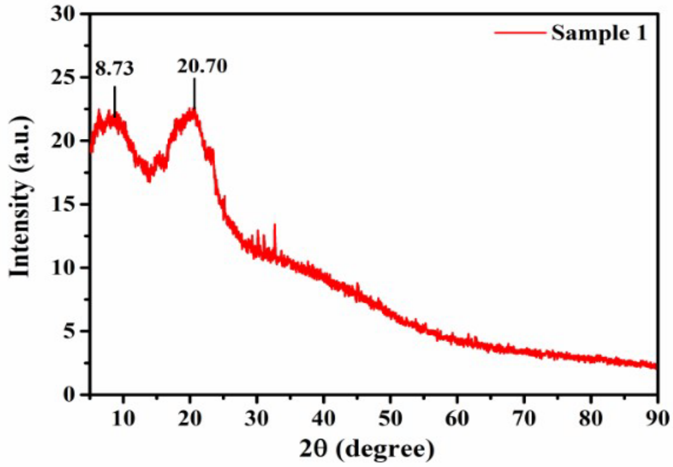

Figure 2. XRD Spectra of Biscuit powder. Where X= 2θ and y= intensity (a.u.).

Table 3: The FTIR analysis of fruits residual flour and biscuit.

Frequency range (cm-1)	Absorbance(a.u.)	Appearance	Group	Compound class	Comments
4000-3500	3453.8	Medium	N-H	Primary amine	
3000-2500	2925.4 2857.8	Medium -	C-H -	Alkane -	
2000-1500	1745.2 1664.2 1565.9 1450.2 1160.9 1020.1	Strong Medium - - - Strong	C=O C=C - C-H C=C CO-O-CO	Esters Alkene Alkene Alkane Alkene Anhydrine	
1000-500	715.4 580.4	- Strong	- C-Br	- Halo compound	Benzene derivative

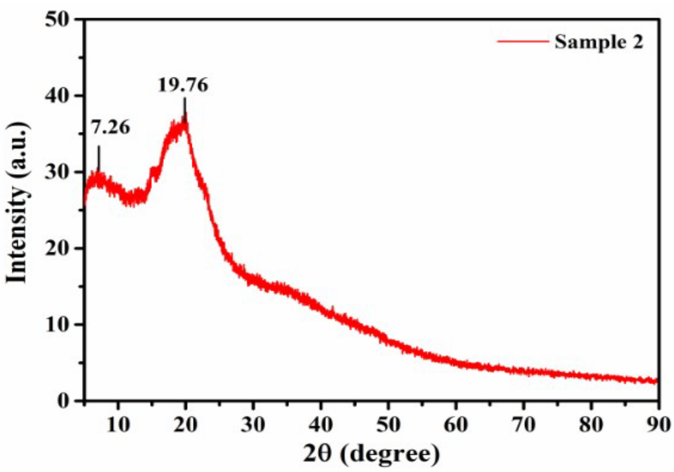

Figure 3. XRD Spectra of Nachos powder. Where X= 2θ and y= intensity (a.u.).

accompanied by a pH increase and a raise of the total soluble solids (TSS). considering that the FVR flour was produced from whole plants, including peels and seeds, the decrease in the TTA can be explained by the continuous metabolic changes of organic acids into carbon dioxide and water Figure 4 & Table 4. Moreover, high levels of reducing substances, such as tannins, polyphenols and carotenoids, have been described to be present in fruit and vegetable by-products [11].

The pH of the samples was shown in Table 5 and ranged from 4.0 to 7.0, which classify the samples as acidic or slightly acidic flours. The titratable acidity values were also presented in Table 5, and ranged from 1.36 to 2.62 g citric acid 100 g-1.

The acidity of the flours analyzed in this work showed a result compatible with Brazilian legislation, which establishes a maximum limit of 5 % for flour acidity. Acidity is an important quality parameter, especially because it prevents microbial growth and enzymatic reactions, which affects the stability and quality of food products, as well as influencing food flavour. During storage, the assessment of acidity enables observation of product's conservation, since the decomposition process by hydrolysis or oxidation often changes the sensory and nutritional characteristics of the product [7]. In addition, it is an essential measurement for use of a given ingredient in pH-sensitive formulations [8]. The low acidity and water activity of flours of the present study contribute to safety and stability during storage Figure 5.

Concerning the total soluble solids content Table 5, flours presented values ranging from 3.57 to 7.81° Brix. In the food industry, the soluble solids content is used, mainly, in the correction of sugar levels of products, such as sweets, juices, nectar, pulps, ice cream, liquors, among others.

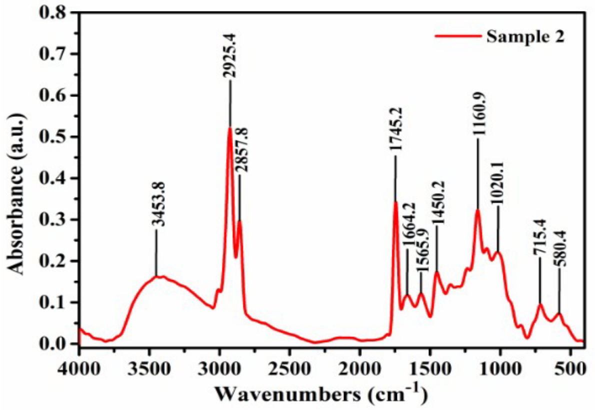

Figure 4. FTIR Spectra of Biscuit powder. Where x= wavelength (cm-1) and y= absorbance (a.u.).

Table 4: The FTIR analysis of vegetable residue flour and Nachos.

Frequency range (cm^{-1})	Absorbance(a.u.)	Appearance	Group	Compound class	Comments
4000-3500	3463.5 3453.8	Strong -	O-H -	Alcohol -	Inter-molecular bond
3000-2500	2925.4 2856.1	Medium -	C-H -	Alkane -	
2000-1500	1745.2 1666.1 1565.9 1457.9 1162.8 1105.1	Strong - Medium - Strong -	C=O - C=C C-H S=O C-O	O-lactone Conjugated ketone Cyclic alkene Alkane Sulfone Secondary alcohol	Y:1770 Methyl group
1000-500	719.3 576.6	Strong -	C=C C-Br	Alkene Halo compound	Disubstituted (cis)

Table 5: Physio-Chemical Properties of biscuit and nachos added with fruits and vegetable residue flour.

	Biscuit	Nachos
Aw	0.21	0.38
pH	4.0	7.0
TTA	1.36	2.62
TSS	3.57	7.81

Table 6: Proximate composition of biscuits and nachos added with fruit and vegetable residue flour.

Fractions ($g\ kg^{-1}$ d.b.)	Fruit & vegetable residue flour	Biscuit formulation	Cereal formulation
Moisture	65.8	175.5	53.7
Ash	25	14	18
Protein	48.9	55.4	32.3
Fat	96.4	97.2	73.0
Crude fibre	83.5	72.4	57.1
Carbohydrate	539	542	331
Calories (kcal/100 g)	256	326	264

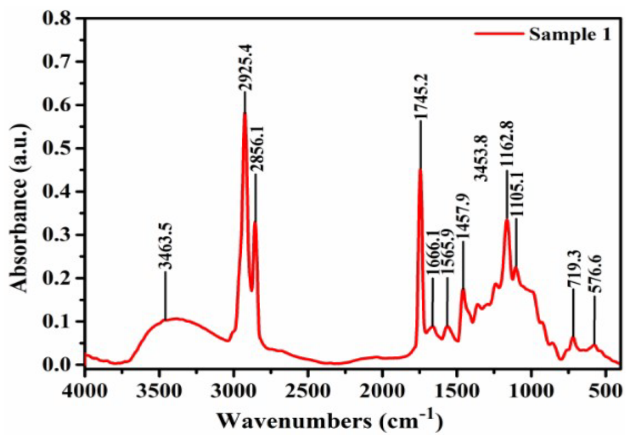

Figure 5. FTIR Spectra of Nachos powder. Where x= wavelength (cm-1) and y= absorbance (a.u.).

All flours had low water activity (Aw), with values ranging from 0.21 to 0.38, as shown in Table 5. The free water, represented by the water activity, is directly related to the physio-chemical and microbiological changes in foods during storage, which interferes with their conservation [11], once water molecules weakly associated with other food constituents can effectively participate in degradation reaction when compared to the strongly associated water molecules

According to Alzamora et al., Aw values lower than 0.60 prevent microbial spoilage, once they prevent the growth of micro-organisms. Thus, the samples of the present study are below the limit the microbial growth.

Values expressed as mean ± standard deviation. By SPSS test ($p<0.05$), for fruit & vegetable residue flour, biscuits & nachos. Aw = Water activity, pH = Hydrogenionic potential, TTA = Total titratable acidity, TSS= Total soluble solids.

Proximate composition

The proximate composition of FVR flour indicated low humidity and high levels of available carbohydrates, fibres, proteins, ash and lipids. The high concentration of carbohydrates, proteins and lipids gave a caloric value of 256 kcal/100g. The high concentration of carbohydrates and fibres resulted from the main components of the FVR flour; peels and seeds, which were rich in starch, cellulose, hemicelluloses, lignin, pectin and other bio-polymers. In the same way, these components were responsible for the high mineral concentration. The low moisture content found in FVR flour has a positive influence on storage stability, textural quality, chemical and biochemical reactions. Moreover, the incorporation of FVR in bakery products improved dietary fibre and functional properties [10].

The proximate composition of the developed products is shown in Table 6. The moisture content of the Biscuit is significantly higher than the Nachos, due to the sugar added in this formulation. The protein, ash and fibre contents observed in biscuit and nachos, are significantly higher.

Nachos showed low moisture contents rather than the biscuit, which was baked while the products just rested at RT. Nachos showed good microbiological stability until 60 days. Crude fibre and available carbohydrate contents did not differ with the level of FVR the fibre and protein contents were similar to those found in biscuit [10,11].

Similarly to biscuit samples, the highest fat content was related to the presence of butter, whereas nachos samples presented a very low-fat content.

The increment of FVR flour in all formulations developed promoted a significant improvement in the fibre fractions when compared to similar commercial products.

Values are means ± standard deviations (n=4), for each product, means values followed by different letters within the same line differ significantly (p<o. o5). Refer to Table 1 for biscuit and nachos formulations.

Microbiological tests

All food products designed with the fruit and vegetable flour were compiled with the CODEX Alimentarius standards and were negative for Salmonella sp., Coliforms (at 30°C to 45°C) and *Escherichia coli* (o.5 MPN g^{-1}). All samples met the standard set for specific counting of each category according to the Indian standard regulation.

The evolution of the microbiological profile of the samples during storage until 60 days was also analyzed, except for the biscuit, that after 30 days presented visible growth of moulds and yeasts being consequently discarded, all samples met the standard set for specific recommendations of Indian standard regulation for each category and did not present exceeding microbiological limits or degradation symptoms for 0, 30 and 60 days. The growth of moulds and yeast in the biscuit after 45 days of storage is related to the high moisture content found in these samples. For the conservation of these products additional studies, changing the packaging or the processing and adding preservatives should be carried out. Nachos, FVR flour and biscuit samples presented a regular profile in the moulds and yeast counts ranging from 220 CFU g^{-1} for Biscuits and 45 CFU g^{-1} for Nachos and 30 CFU g^{-1} for FVR flour in the time zero. During the storage period, all samples presented counts inferior to 10 CFU g^{-1}.

For all samples analysed, the microbiological examination for Staphylococcus aureus was minimal (<0.5 MPN g^{-1}) and are within acceptable limits (<100 MPN g^{-1}, for vegetables dehydrated, dried or freeze-dried; <350 MPN g^{-1}, for nachos and biscuits). The counting of Bacillus cereus ranged from <15 to 35 CFU g^{-1} being within the legal standards for nachos.

Because microorganisms play a significant role in the determination of shelf-lives of food products, we investigated the level of viable aerobic mesophilic bacteria. The results, expressed as log CFU^{-1}, ranged from 7.13, 7.95 to 7.50 for the FVR flour, respectively after 0, 30, 60 days of storage. The counting for biscuits and nachos samples were in the same range but decreased during storage (7.04 to 1.28 and 4.18 to 1.03, respectively for biscuits and nachos after 0 to 60 days). Since there is no standard value specified for the presence of these microorganisms in food products. Therefore, these numbers have only an informative purpose.

Conclusion

The evaluation of the prepared flours showed water activity and pH favourable to the conservation of microbiological quality during storage. Flours and developed products showed higher water solubility than milk solubility, in addition to greater water and milk absorption compared to fat absorption. The results indicated the potential for use in food processing. Therefore, it is suggested that future work use the flours analyzed in this study.

Results showed that the high fibre, protein and mineral contents of the FVR flour are potentially suitable for use in food applications as a new-calorie and functional raw material. The designed products presented high fibre content, and micro-biologically stable. This research promotes the reduction of food waste since whole plant tissues have been used leading to the maximum exploitation of food raw materials. XRD showed the Carbon related material such as; fructose, glucose, sucrose etc which is graphite in structure and amorphous in nature. FTIR showed the presence of Vinylidene, methyl group, amine, alcohol, esters, lactone, alkane and alkene compounds and O-H and N–H, C-H, C=O, C=C, CO-O-CO bonds.

Recommendation

This product would be used for diabetes, CVD, thyroid, obesity and gastrointestinal diseases.

These nachos and biscuits are for all age group.

The FVR flour-based biscuit and nachos are cheap in cost and can be used daily to overcome the deficiency of nutrients.

Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of the paper.

Acknowledgement

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