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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Functional and sensory properties of cookies prepared from wheat flour supplemented with cassava and water chestnut flours

Anu Bala[1], Khalid Gul[1,2]* and Charanjit Singh Riar[1]

Abstract: Functional and sensory properties of cookies prepared by supplementing different proportions of cassava flour (CF) and water chestnut flour (WCF) blends (0–100%) to wheat flour (WF) were studied. Seven formulations of cookies were prepared from (a) Control (100% WF), (b) 30% WF, 35% WCF and 35% CF, (c) 27% WF, 37.5% WCF and 37.5% CF, (d) 20% WF, 40% WCF and 40% CF, (e) 15% WF, 42.5% WCF and 42.5% CF, (f) 10% WF, 45% WCF and 45% CF, and (g) 0% WF, 50% WCF and 50% CF. Cookies were subjected to physical analysis (cookie diameter, cookie thickness, spread ratio, bulk volume, bulk density, breaking strength, and color analysis) and evaluated for consumer acceptance by descriptive sensory analysis. Cookies prepared from water chestnut and cassava flour had low moisture content (5.63%), low fat (24.87%), higher spread ratio (8.148), decreased *L*, *a* and *b* values (dark color), and low breaking strength than control ones. Sensory evaluation established that cookies prepared from 50% WCF and 50% CF were more acceptable than cookies prepared from other formulations.

Subjects: Food Science & Technology; Environment & Agriculture; Engineering & Technology

Keywords: cookies; water chestnut flour; cassava flour; functional properties; organoleptic properties

1. Introduction
Bakery industry in India is considered as one of the major food processing industry with an annual demand of over 2758 MT (Ministry of Food Processing Industries, 2013). India is known to be the second largest manufacturer of biscuits, first being USA. Bakery products are the most popular food consumed by all age groups and are gaining popularity as processed foods because of their availability, ready to eat convenience, and comparatively good shelf life.

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PUBLIC INTEREST STATEMENT
Water chestnut is an underutilized crop and contains myriad of essential components. It has not been utilized fully in food industries, apart from a few investigations suggesting its incorporation in bakery products. Cassava is a rich source of carbohydrates and readily available in market. This study can help industries to develop gluten-free food products and also help researchers for further research on these underutilized crops.

Celiac disease, an autoimmune disease caused by the interaction of gluten in genetically predisposed individuals (Marsh, 1992), is common in areas of North India where wheat is a staple food (Mir, Gul, & Riar, 2014a). A strict gluten-free diet can fully restore health and improve the quality of life in patients with celiac disease and is therefore the basic line of treatment (Stern, 2008). There is a need for the development of a range of gluten-free products as the demand for these products is increasing worldwide with the increase in the number of individuals diagnosed with celiac disease (Arendt & Dal Bello, 2008). Gluten-free products are developed by using flours that are gluten free, however, persons with celiac disease have a lower intake of fiber as compared to a control group of people on normal diet (Grehn, Fridell, Lilliecreutz, & Hallert, 2001), it is imperative to keep in view the fiber content of the new gluten-free products.

Water chestnut (*Trapa natans*) locally called as “Singhara” in India (Gani, Haq, Masoodi, Broadway, & Gani, 2010), used as a substitute for cereals in Indian subcontinent during fasting days, can be a good replacement for wheat flour (WF) with respect to Celiac diseases caused by indigestion of gluten (wheat protein) (Gul, Riar, Bala, & Sibian, 2014; Mir, Gul, & Riar, 2014b). Cookies prepared from water chestnut flour can also be used as a specialized product during *Navratras* and other sacred or fasting days observed frequently in India. Cassava (*Manihot esculenta*) also called “yucca” or “manioc” serves as the third most important food source in the tropics after cereal crops such as rice and maize. Cassava roots are good and inexpensive source of carbohydrates are considered as a foodstuff of high nutritional value and one of the most economical sources of energy, since the carbohydrate yield is 40% greater than in rice and 20% greater than in corn (Tonukari, 2004). Water chestnut flour (WCF) and cassava flour (CF), both devoid of gluten, can be promising for the development of gluten-free bakery products. Additionally, they have higher fiber content and myriad of nutritional properties justifying their use in the preparation of health foods.

Cookies have gained importance as a preferred way to use composite flours as they are ready-to-eat, provide a good source of energy, and are consumed widely throughout the world (Arshad, Anjum, & Zahoor, 2007; Chavan & Kadam, 1993). Present study was as such carried out to prepare cookies from WF by supplementation with different proportions of WCF and CF and study their functional and organoleptic properties.

2. Materials and methods

2.1. Materials

Water chestnuts were procured from Sangrur, Punjab, and cassava roots were procured from Andhra Pradesh, India, and were stored at 4°C till further use. Bakery shortening, sodium chloride salt, sugar powder, and sodium bicarbonate were all procured from local market of Sangrur, Punjab. Water chestnuts and cassava roots were washed, peeled and cut into pieces, and dried at 70°C for 30 min on perforated trays in a tray drier (M/s. Balaji Enterprises, Saharanpur, India). Subsequently, after cooling they were ground separately in a blender to get flours. Flours were sieved and packed in doubly layered zipped polyethylene films till further use.

2.2. Methods

2.2.1. Proximate composition of flours

Moisture, ash, and fat content of flours were determined according to Association of Official Analytical Chemists (2005) methods. Total carbohydrate was quantified by phenol sulfuric acid method as described by Gul et al. (2014).

2.2.2. Physicochemical analysis of flours

Swelling power and solubility were determined according to the method described by Tester and Morrison (1990). Water binding capacity and oil binding capacity were determined as per the method described by Yamazaki (1953) as modified by Medcalf and Giles (1965). Crude fiber was determined as per the method described by Ranganna (1994). Sample (2 gm) of each flour was taken and digestion was done with 200 ml of H_2SO_4 (0.255 N) for 30 min. Glass beads were added during digestion. Residue was washed with hot distilled water and further digestion was carried with NaOH (0.313 N) for 30 min. Residue obtained was washed again with hot distilled water and further with 15 ml ethanol. The final residue was kept in a hot air oven at 50°C until a constant weight (W_1) was obtained. Residue with weight W_1 was transferred into a muffle furnace and kept at 550°C for 4 h. After cooling weight W_2 was taken and crude fiber was calculated as follows:

$$\text{Crude fiber content}\,(\%) = \frac{(W_1 - W_2)}{(W)} \times 100$$

2.2.3. Bulk density (loose and pack)
Bulk density (loose and packed) was determined by the procedure as described by Mir et al. (2014a). For loose bulk density, an empty and dried 50 ml measuring flask was weighed and flour sample was allowed to fall freely into it up to the mark, with gentle tapping. The flask was weighed again along with the sample. For packed bulk density, the same sample was tapped inside the measuring flask with the help of rubber pad, and more of the sample was added up to the mark before weighing. The results were reported as g/ml.

2.2.4. Color analysis
The color characteristics of the prepared product were assessed using a color spectrophotometer (Model No. i5, GretagMacbeth, Grand Rapids, MI) to determine *L* value (light–dark), *a* value (red–green), and *b* value (yellow–blue). The colorimeter was calibrated with white standard. *L*, *a*, and *b* measurements were evaluated from three samples and the values were averaged. Color was evaluated as the total color difference (ΔE).

$$\Delta E = \sqrt{(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2}$$

where L_0, a_0, and b_0 represent the standard reading and *L*, *a*, and *b* represent the instantaneous individual reading after applying the experimental design.

2.3. Preparation of cookies
Cookies were prepared using a formulation described in Table 1 and as per recipe shown in Table 2. Cookie dough was prepared from different proportions of WF, WCF and CF (as per formulation), 30 g of sugar, 35 g of shortening, and 1 g of ammonium bicarbonate.

2.4. Physical analysis of cookies

2.4.1. Cookie diameter
Diameter (*D*) of cookies was determined by placing four cookies edge to edge. The total diameter was measured in centimeter with the help of a vernier caliper. The cookies were rotated at an angle of 90° for duplicate readings. This process was repeated thrice to get an average value and results were reported in centimeter.

Table 1. Formulation for preparation of cookies

S. No.	Wheat flour	Cassava flour	Water chestnut flour
1	100	–	–
2	30	35.0	35.0
3	25	37.5	37.5
4	20	40.0	40.0
5	15	42.5	42.5
6	10	45	45
7	–	50	50

Table 2. Proximate composition of wheat flour

Parameters	Composition (%)
Moisture	13.0 ± 0.09
Ash	0.98 ± 0.10
Protein	10.7 ± 0.21
Carbohydrate	74.78 ± 0.11
Crude fiber	0.54 ± 0.02
Fat	0.93 ± 0.13

Note: Data represented are mean ± SD for $n = 3$.

2.4.2. Cookie thickness

The thickness (T) of the cookies was determined by placing four cookies stacking on one another. The thickness was measured in centimeter with the help of a vernier caliper. This process was repeated thrice to get an average value and results were reported in centimeter.

2.4.3. Cookie spread ratio

Cookie spread was determined from the diameter and thickness, using the following formula:

$$\text{Spread} = \frac{D}{T}$$

2.4.4. Bulk volume

Bulk volume of cookies was determined with slight modifications to the method described by Mir et al. (2014b).

2.4.5. Bulk density

Bulk density of cookies was determined by the help of bulk volume and weight of cookie, using the following formula:

$$\text{Bulk density} = \text{Weight of cookie}/\text{Bulk volume}$$

2.4.6. Breaking strength of cookies

Breaking strength of cookie was measured using the HDP/BS blade. The individual samples of cookies were placed on the platform and the blade was attached to the crosshead of the instrument. The texture analyzer (TA) setting was kept at:

Probe: Three-point bend ring

Mode: Measure force in compression

Pre-test speed: 2 mm/s

Test speed: 3 mm/s

Post-test speed: 10 mm/s.

2.4.7. Sensory evaluation

The sensory quality and overall acceptability of cookies were carried out on a 5-point scale. The sensory panel involved semi-trained panelists of Department of Food Engineering and Technology. The samples were rated on the basis of the criteria: 5 being highly acceptable and 0 being completely unacceptable with respect to different characteristics.

3. Results and discussions

3.1. Proximate composition of flours

The proximate compositional analysis of WF is presented in Table 3 and that of water chestnut and cassava flours are presented in Table 3. There was a significant variation in overall composition of

Table 3. Proximate composition of water chestnut and cassava flours

Parameters	Water chestnut	Cassava
Moisture	9.0 ± 0.12	10.0 ± 0.05
Ash	2.42 ± 0.22	2.84 ± 0.13
Protein	3.1 ± 0.09	2.3 ± 0.06
Carbohydrate content	83 ± 0.13	78.76 ± 0.34
Crude fiber	1.2 ± 0.3	5 ± 0.12
Fat	0.32 ± 0.11	0.56 ± 0.09
Water binding capacity	91.73 ± 1.31	89.74 ± 1.27
Oil binding capacity	62.35 ± 0.20	60.41 ± 0.60
Swelling power (g/g)	11.28 ± 1.01	16.11 ± 0.08
Solubility	11.63 ± 1.43	14 ± 0.74
Bulk density (Loose) g/ml	0.689 ± 0.1	0.321 ± 0.13
(Packed) g/ml	0.988 ± 0.03	0.522 ± 0.1
Color L^*	78.392 ± 1.70	94.586 ± 2.33
a^*	5.334 ± 1.04	3.197 ± 0.76
b^*	12.991 ± 0.13	12.351 ± 0.05
ΔE	57.87 ± 0.68	73.67 ± 0.45

Note: Data represented are mean ± SD for $n = 3$.

three flours. The moisture content of WCF and CF was lesser as compared to the WF while the ash content was higher in water chestnut and cassava flours. The protein content of WCF and CF was lower while the total carbohydrates were more as compared to WF. These results are in accordance with those reported by Mir et al. (2014a) for WCFs.

3.2. Physical analysis of cookies

Data for physical analysis of cookies is presented in Table 4. Spread ratio or diameter of cookies has long been used to determine the quality of flour for producing cookies (Gaines, 1990). Cookies prepared from water chestnut and cassava flour had more spread ratio as compared to WF cookies which increased with the substitution of more water chestnut and cassava flours. This might be due to more starch content present in water chestnut and cassava flours (Gul et al., 2014; Mir et al., 2014b; Singh et al., 2011). Cookies prepared from WF had more breaking strength than the ones prepared from water chestnut and cassava blend (Table 5).

3.3. Sensory analysis

The descriptive sensory evaluation values for prepared cookies are presented in Table 6. From the results, it was found that the addition of water chestnut and cassava flours resulted in appreciation

Table 4. Physical characteristics of cookies

Formulation of cookies	Diameter (cm)	Thickness (cm)	Spread ratio	Bulk volume (ml)	Weight of cookies	Bulk density (gm/ml)	Breaking strength (Force)	Color characteristics		
								L^*	a^*	b^*
Control (100 g WF)	5.05	0.695	7.266	16.4	10.7	0.652	1.869	74.084	11.029	22.96
30 WF, 35 CF, 35 WCF	5.3	0.697	7.604	16.32	10.69	0.655	1.817	73.259	10.69	23.14
25 WF, 37.5 CF, 37.5 WCF	5.34	0.695	7.683	16.28	10.65	0.654	1.506	72.78	10.907	23.057
20 WF, 40 CF, 40 WCF	5.47	0.695	7.871	16.19	10.65	0.657	1.422	72.445	11.54	24.074
15 WF, 42.5 CF, 42.5 WCF	5.34	0.667	8.005	16.1	10.72	0.665	1.915	72.137	11.836	26.509
10 WF, 45 CF, 45 WCF	5.43	0.665	8.165	16.01	10.72	0.669	1.317	70.744	11.134	22.96
50 CF, 50 WCF	5.43	0.645	8.418	15.92	10.73	0.673	1.575	69.72	10.372	18.533

Table 5. Breaking strength of cookies

Formulation of cookies	Force
Control (100 g WF)	1.869
30 WF, 35 CF, 35 WCF	1.817
25 WF, 37.5 CF, 37.5 WCF	1.506
20 WF, 40 CF, 40 WCF	1.422
15 WF, 42.5 CF, 42.5 WCF	1.915
10 WF, 45 CF, 45 WCF	1.317
50 CF, 50 WCF	1.575

Table 6. Sensory scores of prepared cookies

Sample	Physical appearance	Mouth feel	Color	Oiliness	Stickiness
1	4.9	4.8	4.8	4	2.1
2	4.6	4.5	4.4	3.6	2.1
3	4.7	4.7	4.6	3.6	2.1
4	4.6	4.6	4.7	3.5	2.1
5	4.7	4.8	4.6	3.5	2.1
6	4.7	4.8	4.6	3.2	2
7	4.8	4.9	4.8	3.2	2

from consumer panel. Cookies prepared from formulation 7 (50% WCF and 50% CF) was more acceptable than other formulations. Similar results were reported by Mir et al. (2014b) for cakes by increasing WCF in the formulation.

4. Conclusions

Water chestnut and cassava flours which are gluten-free and readily available were used to substitute WF at various levels to prepare cookies. The cookies prepared from WCF and CF were appreciable in terms of sensory analysis and had lower moisture, fat, and protein content. They were also soft and appealing in color. Further studies on the utilization of water chestnut (underutilized crop) and cassava can help combat celiac disease at the same time to uplift the socioeconomic conditions of people associated with this trade.

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