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Fatty acid profile of water chestnut flour and effect on dough rheology & cookies of wheat flour

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Abstract

The proximate physico-chemical composition and fatty acid profile of water chestnut were studied. The content of unsaturated fatty acids like oleic acid and linoleic acid was significant to the extent of 67.5%; whereas the saturated fatty acids were low to the extent of 30.65% comprising of palmitic acid (21.95%), stearic acid (4.87%). The major fatty acids are linoleic, oleic and palmitic; these accounted for more than 85% of the total fatty acid content. The total essential fatty acids were found to the extent of 35%.The effect of water chestnut on wheat flour dough rheology with respect to farinograph and extensograph were evaluated for water absorption, dough stability, dough development time. The cookies were prepared with the blends of wheat flour and water chestnut flour evaluated for their textural and sensory characteristics which were found to be more acceptable in the 20% blend of water chestnut flour to that of wheat flour.

Keywords: water chestnut, wheat flour, fatty acid content, farinograph, dough rheology.

I. INTRODUCTION

Trapa natans L. var. bispinosa Roxburgh, commonly called as water chestnut is an aquatic plant native to Asia. Water chestnut is an annual, floating (submerged rooted) plant, found commonly on the freshwater surface of lakes, tanks and pools throughout India especially in Punjab, Bihar, Uttar Pradesh, Madhya Pradesh, Tamilnadu, Maharashtra and in some parts of Uttarakhand and similar countries (Takano and Kadono, 2005; Puste, 2004). In India it is locally known as "*Singhara*" is an edible angiospermwarm season cropsfound withtwo popular widely cultivated species viz.,*Trapabispinosa*and *Trapaquadrispinosa*. Although water chestnut fruit is a nutritive but has failed to get all importance and attention of food processors due to its availability for only 2-3 months in a year. The water chestnut is covered with a thick jet-black outer pericarp shaped like a horn protruding from the head of a buffalo. Its main root system adheres in the muddy soils at the bottom of the pond and is connected with floating leaves by herbaceous stems in water body. The physico-chemical analysis of water chestnut fruit have been studied by Majumdar and Jana (1977)andLee & Hwang (1998) to provide the fundamental data. It is grown in India mainly for human consumption either in the form of vegetable, dried to make flour to prepare flatten bread (chapatti) or in the shape of sweet dishes of many kinds according to individual's taste. Water chestnut is an important commodity in food industry because of its unique taste (Parker and Waldron, 1995). Water chestnuts can be used in a variety of recipes because they have a starchy taste that is fairly neutral. Some people claim that their flavour is similar to a bland nut. Water chestnuts also have a firm and crispy texture, which adds to their appeal as an ingredient in stir-fries, salads, or any meals where the vegetables to be used must have a crunchy consistency. The fruits are eaten raw at tender stage and sometimes after boiling and roasting. It is consumed mainly in the form of cooked vegetable, flour or in the shape of sweet dishes of many kinds. It compares well with other foods and is a good source of carbohydrates, proteins and essential minerals. The dark-brown corms (whole fruit) are peeled before cooking or canning. The bulk of the edible region consists of starch-rich, thin walled storage parenchyma similar in appearance to potato, interspersed with vascular strands. However, in contrast to potato, water chestnut is notable for its ability to maintain a firm and crunchy texture after considerable heat treatment during canning or cooking. This property is attributed to the lack of cell separation during cooking (Loh et al., 1982; Klockeman et al., 1991). Usually, the fruits are washed, peeled, sliced and packaged, before commercially sold. However, minimally processed fresh products have relatively short shelf life, because of large amount of tissue disruption and increased metabolism that lead to rapid onset of enzymatic browning.

Trapa bispinosa is a medicinal herb plant that has been used as a nerve tonic from time immemorial (Ambikar et al., 2010). The acrid juice is used for diarrhoea and dysentery. The fruits are used as intestinal astringent, aphrodisiac, anti-inflammatory, antileprotic, in urinary discharges, fractures, sore throat, bronchitis and anaemia (Kirtikar and Basu, 1993), hepatoprotective activity (Kar et al., 2004), free radical scavenging activity (Kim et al., 1997), antitumor and antioxidant activity (Song et al., 2007; Irikura et al., 1972). In view of the consumers demand for natural foods having good therapeutic values, water chestnut extends its high values in many aspects of therapeutic food. The high consumption values of the fresh fruit are probably linked to the high nutritional and organoleptic value, and also to the increasing interest of the consumers towards organic products. Singh et al., (2010); Lee and Hwang (1998) studied physicochemical properties to provide basic data for water chestnut processing and product development. Jain et al., (2012) reported that fruit kernels are juicy and crisp when raw whereas when it is cooked, flesh soften but still remains crunchy.

Cereals are the main source of food for mankind, particularly in developing countries, where one-half of the calorie intake is derived from cereal grains. Most of the nutrients in wheat are present in the outer layers and are lost during the process of milling. The feasibility of fortifying flour, bread, rice, and so on, with different nutrients was reported earlier (Rubin et al. 1977). Hansen et al. (2005) reported that intake of fortified whole meal rye bread resulted in stabilization of the iron status in young women. Breads fortified with a vitamin and mineral supplement showed excellent baking stability and the breads did not have any off-flavour (Emodi and Scialpi 1980). Ranhotra et al. (1997) have studied the bioavailability of calcium in breads fortified with different calcium sources. Studies have been carried out on the effect of processing steps and baking on thiamine, riboflavin and niacin levels in conventional and continuous bread-making process. Studies relating to the effect of different cereal, millets and pulses flours on rheological characteristics of wheat flour dough are available viz., rajma bean (Bharat Kumar and Prabhasankar, 2015), foxtail millet, yellow pea flour. Similarly, Knuckles et al., (1997) reported that β-glucan enriched barley fraction increased water absorption in bread and pasta and breads prepared containing 20% barley fraction were highly acceptable. Studies were carried out to see the effect of both hypoglycemic and cholesterolemic effects of barley in bread making (Asna et al., 1998). High fibre sugar – snap cookies were prepared using different cellulose of different particle size and carboxymethylcellulose or pectin coated cellulose (Gorczyca & Zabik, 1979). The present study relates to find out the fatty acid profile of water chestnut flour (WCF) &effect of WCF on the rheological characteristics of the wheat flour dough and cookies.

II. MATERIALS AND METHODS

A. Procurement of raw material

Fresh water chestnut (*Trapa bispinosa* Roxb.) fruits were purchased from the local ponds of Nagpur, Maharastra State, India. The fruits were washed thoroughly with tap water, excessive water was drained and further stored at refrigerated temperature (4°C) till further use. Standard methyl esters were obtained from M/s Sigma. Other chemicals used were of AR grade and double distilled water was used for the analysis.

B. Physico-chemical properties

Based on the visual experience, size & maturity, grading of the whole fruits were made to three categories viz., under mature, matured and over matured.

C. Physical measurement

Length, width and thickness were measured at nine different points to an accuracy of 0.02 and 0.01 mm using a vernier calliper and micrometre (Mitutoyo, Japan) respectively to have a mean average of all measurement.

D. Density

Bulk density also was determined with 1L volumetric (10 cm dia & 10 cm height) grain measuring cylinder. True density was measured using water displacement method with same material used for bulk density for 1L volume measuring cylinder.

E. Proximate Chemical Analysis

The acidity, total sugars, reducing sugar and starch of the samples were estimated as per the procedure of Ranganna (2002).

The moisture and ash content was calculated using the method of AOAC (2007). The protein was estimated using MicroKjeldahl method to get nitrogen content and multiplied with 5.75 to get protein. The fat was extracted by soxhlet extraction method and calculated as per cent.

Alcohol insoluble solids were determined by boiling 20g water chestnut pulp with 300ml of 80 % aqueous alcohol and simmering for 30 minutes, filtering, washing the residue with 80% alcohol and drying the residue at 100°C for 24 hrs (Hart and Fisher, 1971) and expressed in percentage by weight.

F. Fatty acid composition

Fat samples were converted to fatty acid methyl esters (FAME) using sodium methoxideas per standard procedure (AOCS 2003; Method Ce2-66).The fatty acid composition was determined by GC (Shimadzu 2010) using flame ionization detectoroperated under the following conditions: RTX-2330 capillary column (30mmX0.32mm X 0.5μm); gradient elution programmed as 80 to 120°C at 5°C/minincreased to 160°C at 10°C /min, then to 220°C at 5°C/min and held for 6 min; injector temperature 240°C and FID temperature 260°C; carrier gas was nitrogen at a flow rate of 1 ml/min and the split ratio was 1:20. The fatty acids were identified using authentic standards (Supelco FAME mix with 37 components, Bellefonte, PA, USA), the area percentage was noted and reported as relative percentage. Three injections were made and the average value is reported.

G. Dough Rheological characteristics

The powdered chestnut flour was incorporated in the wheat flour at different formulations and studied for the dough rheological characteristics by farinograph & extensograph as approved by AACC methods (AACC 2000).

Blends of 0%, 5%, 10%, 15%, 20% and 25% were prepared by substituting the wheat flour with water chestnut flour. The effect of different WCF levels on dough rheology was determined by Farinograph (Model: E-380, Brabender OHG, Duisburg, Germany) according to the standard AACC (2000) methods. Parameters measured were water absorption, dough development time, dough stability and mixing tolerance index. The elastic properties of dough with different levels of WCF were measured using extensograph (Brabender, Duisburg, Germany) according to the standard (AACC 2000) methods.

The parameters studied were resistance to extension (*R*), extensibility (*E*), ratio figure (*R*/*E*) and energy (Area).

H. Preparation of cookies

Cookies were prepared using blends of wheat flour:WCF in the ratio of 100:0, 90:10, 80:20 and 70:30 w/w, sugar powder (50 g), shortening (60 g), vanilla (0.3 g) and water (8 ml). The sugar powder, shortening and essence were creamed together in a Hobart N–50 mixer (Ontario, Canada) at 173 rpm for 5 min. Then water was added and mixed for 1 min at 58 rpm and 2 min at 173 rpm. Finally mixed flour(100 g)was added and mixed for 2 min at 58 rpm. The cookie dough was sheeted to 10 mm thickness and cut into circular shape using 5 cm diameter cutter. The cookies were then baked at 180°C for 16–17 min. The cookies were thoroughly cooled and packed in metalized polyester pouches (Jyotsna Rajiv *et al*., 2012).

I. Fracture strength (snap test)

The snap test was conducted using a 3-point bending rig attached to texture analyzer. The distance between two beams was 15 mm. Another identical beam was brought down from above at a pre-test speed:2.0 mm/s, test speed:0.5 mm/s, post-test speed:10.0 mm/s, distance:5 mm to contact the cookie. The downward movement was continued till the cookie broke. The peak force was reported as fracture strength.

III. RESULTS AND DISCUSSION

A. Physical analysis

It is revealed from the table 1 that average weight of under matured, matured and over matured whole water chestnut varies from 9.5 to14.2 g; average volume varies from 9.5 to 12.5 ml and density in the range of 0.995 to 1.137 which is in agreement with the Rodriguez *et al*., (1964). The water chestnut is in triangular bull's head shape and therefore width varies from top to bottom wherein the average width at broader end was 37, 42, and 46 mm and lower end 19, 24 and 26 mm for under matured, matured and over matured whole fruits respectively; whereas height varies from 26 to 34 mm depending upon its maturity. The thickness was found to be from 14 to 16 mm.

The peeled water chestnut fresh fruits dimensions are mentioned in table 1 wherein the average width at broader end was 33, 36, and 37 mm and lower end 15, 17 and 19 mm for under matured, matured and over matured peeled water chestnut fruits respectively; whereas height varies from 21 to 25 mm depending upon its maturity. The thickness was found to be in the range of from 13 to 15 mm. The dimensions measured were found to be directly proportional to increasing maturity indices.

B. Chemical composition

The chemical analysis of water chestnut peeled kernels was carried out and presented in Table 2. The moisture content in under matured kernel was 88.4% (wet basis), higher as compared to matured kernel (84.5%) and over matured kernel (78.2%). This is in accordance to Rodriguez *et al*., (1964). Due to considerable moisture content, it is believed to suppress stomach and heart burning on consumption at breakfast (Puste, 2004). Total ash content was found in the range of 0.52 to 0.86% with increase in maturity attributed to decrease in moisture content on maturity which is in lower range as compared to reported by Singh *et al*., (2010) may be due to difference in variety and geophysical area. It is reported that water chestnut is a good source of mineral containing potassium (0.41%), iron (0.21%) and manganese (0.08%). The total protein in dried kernel powder was found to be 8.7% which is higher than reported by Singh *et al*., (2010). The difference could be attributed to variety and topography area of cultivation. The source of protein indicates a good source amino acids which may give health benefit as reported by Kar *et al*., (2004).

The total sugar and reducing sugar was found to be decreasing from 4.5 to 3.8% and 3.6 to 2.4% with increase in maturity which could be attributed to increase in acid content on maturity and increase in starch content from 2.74 to 10.48%. Similar results were reported by Rodriguez *et al*., (1964). The alcohol insoluble solids were found to be 7.2%, 10.32% and 20.54% for under matured, matured and over matured water chestnut kernels.

C. Fatty acid profile of water chestnut

In view of the literature cited for the medicinal values of water chestnut, it was envisaged to study the fatty acid profile of water chestnut which was not reported elsewhere hitherto. The fatty acid profile of water chestnut sample is presented in Table 3. It has been found that though the crude fat of water chestnut is only 1.8% on dry basis but it is rich in palmitic acid (21.95%) apart from unsaturated fatty acids viz.,oleic acid and linoleic acid, The linoleic acid (33.01%) and oleic acid (32.80%) were dominant respectively among the unsaturated fatty acids. It is interesting to note that the content of unsaturated fatty acids like oleic acid and linoleic acid was significantly higherto the extent of 69.29%; whereas the saturated fatty acids were to the extent of 30.65% comprising of palmitic acid, stearic acid (4.87%) with meager quantum of lauric acid, myristic acid, behenic acid, lignoceric acid. The omega-3 fatty acids content was2.09% and the total essential fatty acids were found to be to the extentof 35%.Since the oil in rich in monounsaturated fatty acids (MUFA) (34.19%) and polyunsaturated fatty acid (PUFA) 33.84%, it will have the ability to reduce LDL cholesterol while possibly increasing HDL cholesterol (O'Brien, 2004) similar to that of rice bran oil and peanut oil.

D. Rheological Characteristics

The farinograph characteristics (Table 4) revealed that a decrease in the water absorption with increase in the level of the water chestnut flour and wheat flour blend, which ranged from 77.4 to 66.6% for the control and 25% replacement of water chestnut flour with that of wheat flour formulation respectively. This may be because of the reduction in gluten and damaged starch content in the blends as durum flour was replaced with WCF. As gluten content is responsible for water holding capacity and forms a network with starch molecules and results in increased water absorption capacity. Similar farinograph trends have been reported previously for replacement of wheat with that of legume flour or protein concentrate (Rasmay, Shatanovi& Hassan 2000). Many of these effects can be attributed to weakening of the gluten matrix due to the incorporation of other flours which contains no gluten. The dough development time was increased from 5.0 min to 6.5 min. with increase in WCF content in blends. The results were in confirmation with the study carried out by supplementing legume flour in semolina which increased the dough development time (Bahnassey & Khan, 1986). Whereas dough stability time had no significant difference on replacement of wheat flour with that of WCF, except for a minute decrease from 3.3 min to 2.8 min. This might be attributed to delay in gluten hydration and gluten network formation. Similar results were reported earlier wherein increase in dough development time and decrease in dough stability time with the incorporation of pea flour to the noodle blend (Bharat Kumar and Prabhasankar, 2015[a]) and with the use of legume flour in semolina blend (Bahnassey and Khan, 1986).

The extensibility of the dough (Table 5) was reduced from 103 to 58 mm by increasing the proportion of water chestnut in the blends of wheat flour; and the energy for extension also has been found to be in reducing trend from 46 to 38 cm^2 for the control and 25% water chestnut flour blend with wheat flour. This could be attributed to the reduction in the gluten content by addition of water chestnut flour.Extensograph studies have also shown an increase in the ratio of resistance to extension to extensibility and ranged from 3.1 to 8.3 with the increase in water chestnut flour.

E. Quality of cookies

Cookies were prepared using blends of wheat flour:WCF in the ratio of 100:0, 90:10, 80:20 and 70:30 w/w. The photograph of cookies is shown in Fig.1. The spread ratio was higher for cookies made from control and decreased with increasing the proportion of water chestnut flour although the decrease was neither significant nor persistent as shown in Table 6. Spread ratio is affected by the competition of ingredients for available water (Claughton *et al*., 1989). Ingredients which absorb water during mixing will reduce it. Lower oven rise during baking of dough containing water chestnut flour contributed for the same. Tangkanakul *et al*., (1995) reported that spread factor of cookies decreased with increasing levels of fibre. Addition of water chestnut flour resulted in decrease in oven rise during baking process which resulted in decrease in average diameter and width in comparison to control sample and hence spread ratio of cookies got reduced constantly with the increase in water chestnut flour proportion.

The fracture strength also increased progressively with the increase in water chestnut proportion from 36.08 to 60.30N Table (6). This may be attributed to the fact that water chestnut flour having lesser fat content than that of wheat and thus is considered drier flour. Gas retention is a property of gluten, awheat protein. During dough development, the gluten becomes extensive and strong. This allows the dough to rise and also prevents easy escape of the gas during baking, thus, providing an open and porous texture for the baked product.

Cookies started loosing its original flavour and texture with the increase of water chestnut flour. Maximum of 30% flour can be blended with wheat flour to get desired cookies with slight flavour of water chestnut.

F. Sensory evaluation of water chestnut cookies

It was found that cookies blended with 20% of water chestnut flour were widely acceptable for its different sensory attributes and depicted in Fig.2. And its overall acceptability is almost near to the control sample. 30% blended cookies had good texture but its mouth feel and flavour was very low. At least 20% water chestnut flour can be blended to wheat flour to get good quality cookies without adding any flavours.

IV. CONCLUSION

The higher moisture content in water chestnut kernel was believed to suppress stomach and heart burning on consumption at breakfast. The total protein in dried kernel powder was found to be 8.7% indicates a good source amino acids which may give health benefit. Though the crude fat of water chestnut is only 1.8% on dry basis but it is rich in palmitic acid (21.95%) apart from unsaturated fatty acids viz.,oleic acid and linoleic acid. It is interesting to note that the content of unsaturated fatty acids like oleic acid and linoleic acid was significant to the extent of 67.5%; whereas the saturated fatty acids were low to the extent of 30.65% comprising of palmitic acid (21.95%), stearic acid (4.87%). The lower saturated fatty acid content is beneficial as World Health Organization recommends only 10% total energy intake from saturated fats. The major fatty acids are linoleic, oleic and palmitic; these accounted for more than 85% of the total fatty acid content. The total essential fatty acids were found to the extent of 35%. The omega-3 fatty acids were found to be 2.09%.Since the oil is rich in monounsaturated fatty acids (MUFA) (34.19%) and polyunsaturated fatty acid (PUFA) 35.10%, it will have ability to reduce LDL cholesterol while possibly increasing HDL cholesterol. It was found that cookies blended with 20% of water chestnut flour were widely acceptable for its different sensory attributes. And its overall acceptability is almost near to the control sample. 30% blended cookies had good texture but its mouth feel and flavour was very low. At least 20% water chestnut flour can be blended to wheat flour to get good quality cookies without adding any flavours. Hence it may be further explored for its amino acid content in future studies so as to evaluate the quality of proteins from water chestnut.

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Table 1: Physical characteristics of fresh whole fruit and peeled water chestnut kernel

Maturity	Avg. Length (mm)	Avg. width (mm)	Avg. Thickness (mm)	L/H Ratio	Average weight (g)	Average volume (ml)	Density
Fresh whole fruit of water chestnut							
Under mature	28.78	26.43	14.12	1.089	9.498	9.45	0.995
Mature	32.43	30.22	14.96	1.073	12.564	12.2	1.030
Over mature	34.16	33.34	16.04	1.025	14.218	12.5	1.137
Fresh peeled water chestnut kernel							
Under mature	24.70	21.14	12.86	1.168	7.241	7.20	1.006
Mature	26.23	23.08	14.27	1.136	8.396	8.28	1.014
Over mature	27.69	25.31	14.88	1.094	10.162	9.95	1.021

*Each value represents the average of triplicate with a significant difference at $P \geq 0.05$

Table 2: Chemical Composition of Peeled Water Chestnut

Parameters	Under mature	Mature	Over mature
Moisture	88.4	84.5	78.2
Ash	0.52	0.623	0.86
Reducing Sugar	3.62	3.14	2.43
Total Sugar	4.5	4.2	3.8
Acidity (as % anhydrous citric acid)	0.126	0.152	0.168
Starch (%)	2.74	5.32	10.48
Alcohol insoluble solids (% AIS)	7.2	10.32	20.54
Fat (%)	0.18	0.20	0.21
Protein (%)	0.83	0.86	0.95

*Each value represents the average of triplicate with a significant difference at P≥0.05

Table 3: Fatty acid composition of fat extracted from chestnut flour

Fatty acids	*Relative percentage
Lauric acid, 12:0	0.96±0.16
Myristic acid, 14:0	0.77±0.07
Palmitic acid, 16:0	21.95±1.14
Palmitoleic acid, 16:1	0.27±0.02
Stearic acid, 18:0	4.87±0.12
Oleic acid, 18:1	32.80±0.65
Linoleic acid, 18:2	33.01±0.50
Linolenic acid, 18:3	2.09±0.02
Arachidic acid, 20:0	0.83±0.09
Eicosenoic acid, 20:1	0.60±0.03
Behenic acid, 22:0	0.54±0.05
Erucic acid, 22:1	0.52±0.02
Lignoceric acid, 24:0	0.52±0.16
□□Saturated fatty acids	30.65
□ Monounsaturated fatty acids	34.19
□□Unsaturated fatty acids	69.29

Table 4: Effect of water chestnut flour on Farinograph wheat dough rheology

Sample parameter	Control	5%	10%	15%	20%	25%
Water absorption capacity %	77.4	74.8	72.6	71.1	68.7	66.6
Dough Development time (min)	5	5.5	5.3	5	6.4	6.5
Dough Stability time(min)	3.3	3.1	2.9	2.9	2.8	2.8
Tolerance index (FU)	66	63	63	78	57	55
Time to breakdown (min)	6.4	7.1	6.9	6.4	8.2	8.7

*Each value represents the average of triplicate with a significant difference at $P \geq 0.05$

Table 5: Effect of water chestnut flour on Extensograph wheat dough rheology

	Control	5%	10%	15%	20%	25%
Energy (cm^2)	46	44	48	44	36	38
Resistance to ext. (BU)	315	308	372	414	356	366
Extensibility (mm)	103	97	95	73	67	58
Max. (BU)	319	308	373	438	403	483
Ratio Number (max)	3.1	3.2	3.9	6	6.1	8.3

*Each value represents the average of triplicate with a significant difference at $P \geq 0.05$

Table 6. Spread ratio& fracture strength of the water chestnut cookies

Flour	Diameter (mm)	Thickness (mm)	Spread ratio	Fracture strength(N)
Control	7.16	1.02	7.04	36.08
10% WCF	7.02	1.08	6.48	41.61
20%WCF	6.96	1.14	6.09	54.18
30%WCF	6.33	1.19	5.33	60.30

*Each value represents the average of triplicate with a significant difference at $P \geq 0.05$

Fig 1. Water chestnut flour blended cookies.

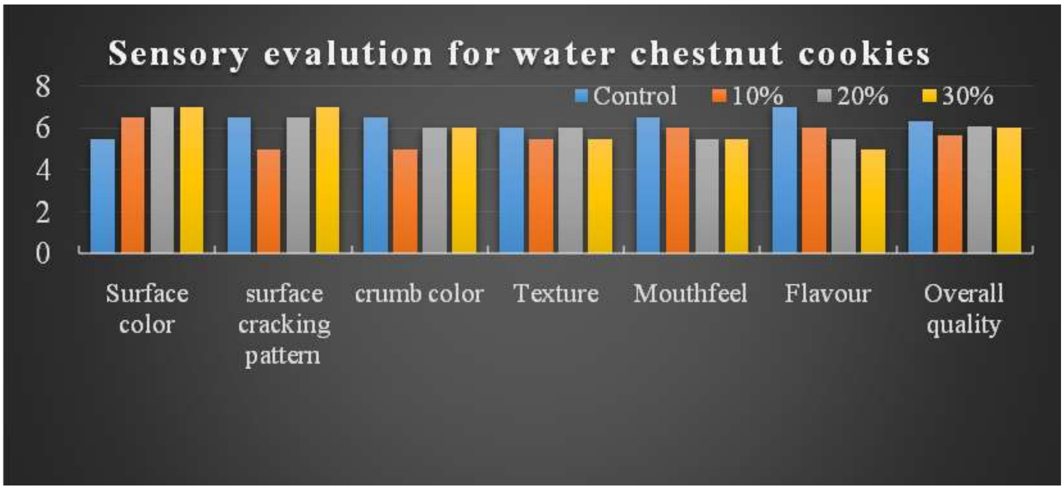

Fig 2. Sensory evaluation of water chestnut cookies

