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Full Length Research Paper

Effect of incorporating sweetpotato flour to wheat flour on the quality characteristics of cookies

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Textural and sensory properties of cookies were studied by supplementing various proportion of sweetpotato flour (0 - 100%) to the wheat flour. The cookie dough was subjected to rheological analysis and texture profile analysis by using TA-XT2i (SMS) in order to determine dough hardness, cohesiveness, springiness, adhesiveness etc. Spread factor, puncture force and fracture strength of the cookies were also determined. Water absorption increases from 29 to 169% with increasing the proportion of sweetpotato flour. The control dough had cohesiveness and adhesiveness values of 0.295g/s and 19.314g/s. The cohesiveness of dough with 20% sweetpotato flour and 80% of wheat flour increased to 0.480 g/s and then decreased with increasing percentage of sweetpotato flour. Sweetpotato flour lowered the spread factor from 6.666 to 6.150 with increasing its level from 0-100%. Sensory evaluation revealed that increasing levels of sweetpotato flour (60%) lowered the overall acceptability (2.7) because of taste and distinct flavor developed during baking.

Key words: Sweetpotato flour, cookies dough, rheological characteristics, texture.

INTRODUCTION

Sweet potato (*Ipomoea Batatas Lam)* is the seventh most important food crop in the world. It is grown in many tropical and subtropical regions. Among the world's major food crops, sweetpotato produces the highest amount of edible energy per hectare per day (Horton and Fano, 1985). India has a long history of sweetpotato cultivation. In India, the area covered under this crop in 2005, was 100,000 Ha and production was 900,000 MT (FAO, 2006). Sweet potato has a large potential to be used as a food in developing nations with limited resources because of its short maturity time and ability to grow under diverse climatic condition and on less fertile soil. Options for sweetpotato products are numerous, and based on recent diagnostic assessments carried out in developing countries; dried chips, starch, and flour were identified as among the most promising (Collins, 1989) . Sweet potato flour can serve as a source of energy and nutrients (carbohydrates, beta-carotene (provitamin A), minerals (Ca, P, Fe, and K)), and can add natural sweetness, color, flavor and dietary fiber to processed food products (Woolfe, 1992; Ulm, 1988). Traditionally cookies are made from wheat flour and there is little record of rice being used in cookie type products. Small quantities of other cereal flours or starches can be added to give special flavors or structural properties.

Dough is the intermediate stage between flour and the bakery product. The rheological characteristics of the dough are very important, as they influence the machi-nability of the dough as well as the quality of the finished product (Faridi and Faubion, 1986). These characteristics depend on several factors such as ingredient quality and quantity, mixing conditions, resting time and temperature of the wheat flour dough (Bloksma and Bushuk, 1988). In recent years the interest in high fiber content in foods has greatly increased and brown flours or high extraction flours are being used. Abd and Moniem (1994) studied high dietary fiber cookies by replacing wheat flour with 6
– 24% of cereal by-products like corn bran, rice bran or barley husk but no objective evaluation was carried out.

Because of the distinct properties, the use of sweetpotato flour in the preparation of bread is restricted. Most of the researchers in this aspect found a substitution level of 10 – 15% for wheat flour on a dry weight basis as the most acceptable (El-sahy and Siliha, 1988; Lopez and Villagarcia, 1984). Hagenimana et al. (992) reported that he addition of orange-fleshed sweetpotato in buns, cha-

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Table 1. Different combinations of sweetpotato flour and wheat flour for cookie preparation.

S.N	Sweetpotato Flour (%)	Wheat flour (%)
1	00	100 (Control)
2	20	80
3	40	60
4	60	40
5	80	20
6	100	00

pattis, and mandazis greatly increased the content of total carotenoids in these products. Most of the technical research on sweetpotato flour has been focused on the development of new products using sweetpotato flour rather than on efficient methods to produce and store the flour (Lizado and Guzman, 1982). Addition of various proportion of sweetpotato flour in wheat flour can increase the nutritive values in terms of fibre and carotenoids. This also helps in lowering the gluten level and prevent from coeliac disease (Tilman et al., 2003).

Our approach in the present study was to replace the wheat flour in cookies by sweetpotato flour (gluten-free flours) in order to increase the fiber and other nutrients. The objective was to develop cookies with good taste, texture and appearance, which resembles as closely as possible to the wheat flour based product. The textural property and sensory quality of cookies are taken into consideration to improve the quality of cookies.

MATERIALS AND METHODS

Sweet potatoes of variety PSP-21 were procured locally from the field after harvesting. Roots were washed, trimmed and cured to make them free from soil and other foreign materials, rotting, insect damage. Trimming was carried out manually and curing was done at 35°C for 2 - 3 days, stored at 12 -15°C at 80%RH till further use.

Laboratory grade potassium metabisulphite (KMS), NaCl and citric acid were purchased from M/s. Brightways Agencies, Chandigarh, India.

Flour preparation

Treated sweet potatoes were peeled and cut into thin slices manually. Slices were directly immersed into 1% NaCl solution and then immersed in solution containing KMS (1%) and citric acid (0.5%) for 30 min. Drying of sweetpotato slices was done on perforated trays in a tray dryer (M/s. Balaji Enterprises, Saharanpur, India) at 55°C till 7 - 8% moisture content and then stored in air tight container till further use.

The dried chips were milled into flour using the laboratory grinder (M/s. Sujata, New Delhi, India) and passed through 80 mesh sieve to obtain flour of uniform size. The flour was then packed in air tight container and stored under refrigeration condition till further used.

Wheat flour, sugar and shortening were procured from the local market. The wheat flour used had protein and ash content of 9.2 and 0.65%, respectively. The sugar used was ground coarsely in a laboratory grinder (Sujata, India).

Analysis of sweetpotato flour

Sweetpotato flour was analyzed for moisture, protein, ash, lipids, crude fiber and falling number according to AACC (1995) methods. Starch and sugars (total and reducing) were determined according to methods of AOAC (1981).

Water absorption

Water absorption of flour was determined with little modification to the method reported by Anderson et al. (1969). Five gram flour of each sample was weighed into a centrifuge tube and 30 ml of distilled water was then added and mixed thoroughly. This was allowed to stand for 30 min and centrifuged at 3,000 rpm for 15 min. The supernatant was then decanted and the sample weighed again. The amount of water retained in the sample was recorded as weight gain and was taken as water absorbed. The results were expressed as weight of water absorbed in grams per 100 g dry matter of the sample.

Odor evaluation

Sweetpotato flour odor was subjectively evaluated by a panel of ten members. In this test, distilled water was added to sweetpotato flour to give a final moisture content of 40%. After homogenization, the flour was put aside in a closed transparent plastic container for two hours and then presented to each panelist in a randomized complete block design. During evaluation, each panelist placed the plastic container near their nose, removed the cover and took a deep breath to smell the solution. The perceived odor intensity of the flour was scored on an interval category scale ranging from low intensity to high intensity. This was repeated three times using different code numbers on each occasion (Owori and Hagenimana, 2000)

Color measurement

Color of flour and cookies samples was measured by colorimeter CR-300 (Ramsey, N.J., U.S.A.) and recorded in the L* a* b* color system. The colorimeter was calibrated using a standard white plate. Samples were placed in the sample holder for measurement. Color values were recorded as ‘‘L*’’ (lightness), ‘‘a*’’ (redness), and ‘‘b*’’ (yellowness). From a* and b* values, the hue angle $\tan^{-1}\left(b^*/a^*\right)$ and chroma $\sqrt{\left((a^*)^2\right)+\left((b^*)^2\right)}$ were calculated.

Cookie formulation

Cookie dough was prepared according to the following formula: 100 g flour (contain different proportion of sweetpotato flour and wheat flour, Table 1), 30 g sugar, 35 g shortening, 1 g sodium chloride, 0.5 g sodium bicarbonate, 1 g ammonium bicarbonate, 0.5 g baking powder, and various proportion of water to make required consistency of dough.

Dough preparation

Cookie dough was made in a laboratory mixer (Hobart mixer, Model N50, Canada). Fat and sugar was creamed in a mixer with a flat beater for 2 min at slow speed. Dough water containing the baking chemicals and sodium chloride was added to the resulting cream, and mixed for 5 min at high speed to obtain a homogeneous mixture. Finally, flour containing various proportion of sweetpotato

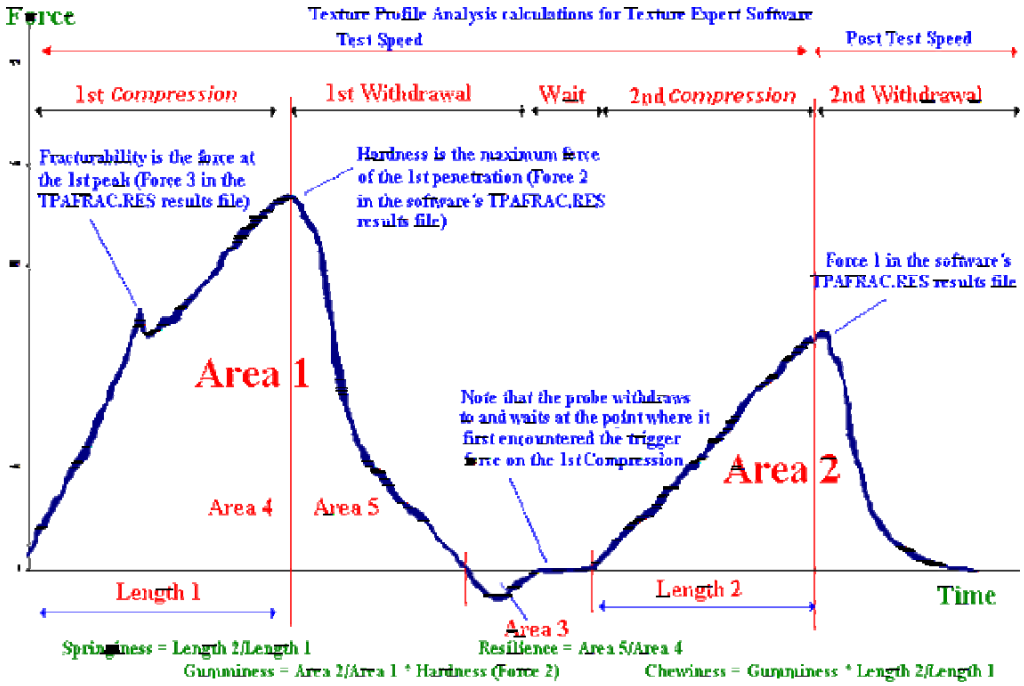

Figure 1. Typical texture profile curve for dough.

flour, which had been sieved twice with baking powder was added, and mixed for 3 min at medium speed. The dough was rested for 30 min before evaluation.

Rheological characteristics of

dough Texture profile analysis

Texture profile analysis of the dough was carried out by texture analyzer (Model TA-XT2i, Stable Micro Systems, Haslemere, U.K.). under the following conditions: Probe (P75)/75mm ; Load cell, 50 kg; Pre test speed,3.0mm/s; Post test speed, 10.0mm/s.

Dough samples were obtained by sheeting with a rolling pin over a rectangular platform and frame of height 1.0 cm to give a sheet of 1.0 cm thickness. The sheeted dough was cut into a circular shape using cutters of 4.5 cm diameter. The cylindrical dough of 4.5 cm in diameter and 1.0 cm thickness was used for these studies. The real-time plots (Figure 1) were analyzed for the following: (1) dough consistency (Ns), the combined area of the two resistance peaks; (2) dough hardness (N), the maximum resistance to the first compression peak (height of peak 1); (3) dough cohesiveness, the ratio of the areas of the two resistance peaks (*A*2/*A*1); (4) dough adhesion (Ns), the area of the first adhesion peak; (5)Springiness is Length 2/ Length 1. (6) Resilience (Area 2/ Area1).

Cookies preparation

The flow sheet of the cookies making process is shown in Figure 2. The dough was then sheeted to a thickness of 4.5 mm with the help of a rolling pin and an aluminum frame of standard height. The cookies were cut with a cookies die of diameter 55 mm and transferred to a lightly greased baking tray. The cookies were baked at 205°C for 12 min in a baking oven (Continental, India). The baked cookies were cooled and stored in air tight container for 12 h before further analysis.

Evaluation of cookies

Physical characteristics

Spread factor: The cookies were allowed to cool for 30 mins. The AACC (1995) method: 10-50D (200) was used to determine cookies width, thickness, and spread factor. Cookie width (W) was measured by placing 6 cookies edge-to- edge to get the average width in millimeters. Cookie thickness (T) was measured by stacking 6 cookies on top of each other. Width divided by the thickness gave the spread factor.

Fracture Strength (Snap Test)

The 3-Point Bending Rig of Texture analyzer (Model TA-XT2i, Stable Micro Systems, Haslemere, U.K.) was used to determine fracture strength. The distance between the two beams was 40 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 breaks. The peak force was reported as fracture strength.

Density

Density was determined by standard seed displacement method and result was expressed as g/cc (AACC 1983).

Sensory evaluation and statistical analysis

The cookies were evaluated by a panel of 15 members. Samples were evaluated on a desk placed in the air-conditioned laboratory, which provided a quiet and comfortable environment. The cookies were served on a white disposable plastic tray and tap water was provided for rinsing. Mean of 15 evaluations was reported. The de-

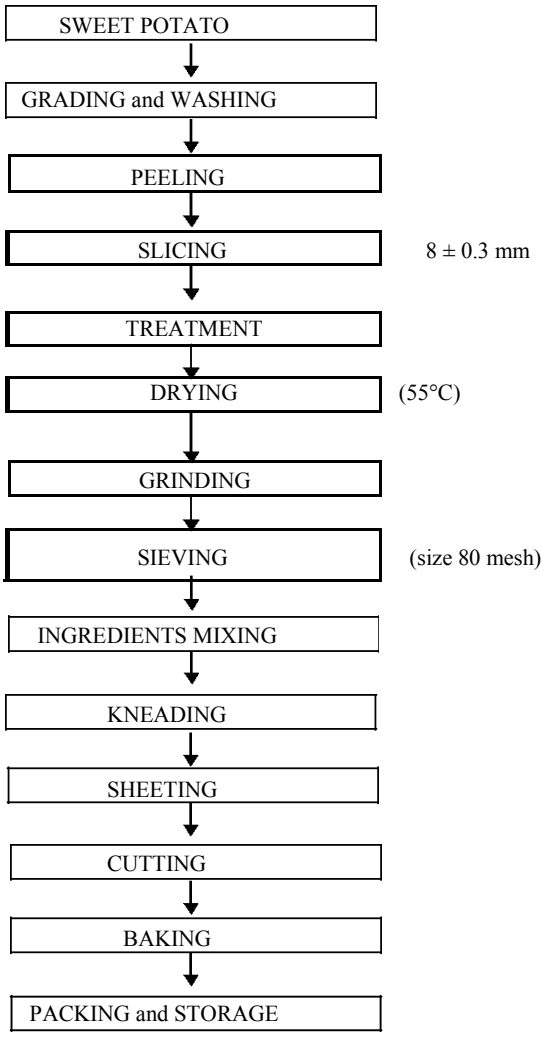

Figure 2. Flow diagrams for preparation of sweetpotato flour cookies.

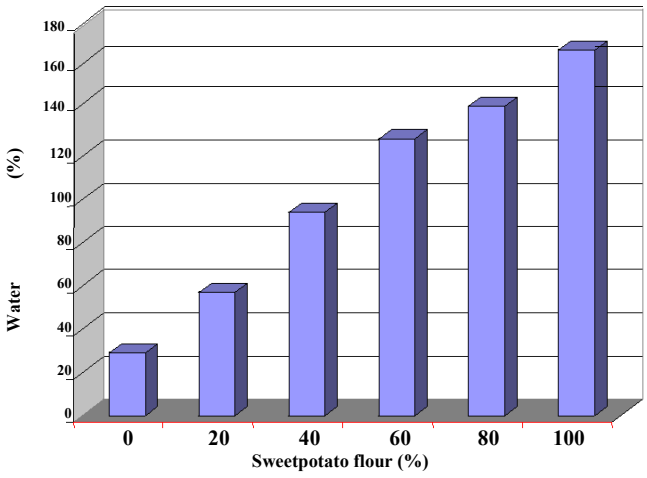

Figure 3. Water absorption of the sweetpotato flour samples at 30°C.

tails of sensory attribute, definitions are given in Table 2. Statistical analysis was done using Minitab Statistical Software (Minitab Inc. USA)

RESULTS AND DISCUSSION

Proximate analysis of sweetpotato flour is presented in Table 3. The moisture content of sweetpotato flour was 8.7%. Sweetpotato flour had very low protein content (2.3%) and high fiber content (9.4%). This high fiber increases the utility of sweetpotato flour in various food products. The starch content in sweetpotato flour was 74.5 (dwb). Ulm (1988) mentioned that the total carbohydrates of the sweetpotato in roots are comprised of approximately 80% starch and 20% simple sugars. Woolfe (1992) divided digestible carbohydrates into starch and total sugars with levels of 87.5 and 12.5% respectively. Sweetpotato flour has distinct odor. Odor intensity of sweetpotato flour is summarized in Table 4**.** It was observed that the controlled sample has lower odor intensity and the intensity of odor increased significantly from 2.5 to 4.2 with the increased proportion of sweetpotato flour. This may be due to the volatile flavor constituents in sweetpotato flour which gave characteristics flavor and enzyme reaction also involved in the change in odor as reported by Purcell et al. (1980).

The water absorption of sweetpotato flour was 172%. This high percentage of water absorption was because of more fiber and sugar content in the flour. Water absorption results **(**Figure 3) showed that increasing the proportion of sweetpotato flour increased the absorption of water. Increase in water absorption lead to the weakened dough and decrease dough development and dough stability. A similar trend also observed by Hamed et al. (1973). Addition of sweet potato flour to wheat flour caused a decrease in extensibility of the dough.

Effect of sweetpotato flour on color values of flour and cookies is shown in Tables 5 and 6. The L* value of flour decreases significantly from 94.43 to 82.38 with increasing the proportion of sweetpotato flour but this value decreased from 62.26 to 48.43 in the case of cookies. The b* value which shows yellowness of flour increased significantly from 9.23 to 21.59 with increasing the proportion of sweetpotato flour. The yellow-orange color of sweetpotato flour was caused by the presence of carotenoid pigments, which affect the red-green chromaticity (Van Hal, 2000).

Texture profile analysis

The textural characteristics of the doughs made from varying proportion of sweetpotato flours, are given in Table 7. Varying the sweetpotato flour and water content changed the textural characteristics of dough signifycantly. The hardness increased significantly from 1105 to 4864.3g in dough prepared from control sample to 100% sweet potato flour. A similar trend was observed for the biscuit dough by (Manohar and Haridas, 1999).

Table 2. Sensory attribute, definitions and extremes.

Sensory Trait	Definition
Initial bite (Texture)	Crisp to hard. (4.9 to 1)
1)Crisp	Cookie suddenly breaks when a small amount of force is applied
2)Crumbly	The cookie breaks easily, forming loose fragment in the mouth.
3)Tender	The cookie is easily broken down upon chewing.
4)Hard	Cookie withstands substantial force on initial bite
Mouth feel	Crunchy to teeth clogging (4.9 to 1)
1)Crunchy	Require repeated chewing to break cookie down. Crunchy sound is heard.
2)Granular	Small particles are detectable when the cookie is chewed
3)Flaky	On chewing a rough paste is formed, containing large irregular pieces.
4)Teeth clogging	Particles stick in the mouth after the paste is swallowed.
Taste	Sweet to burn or caramel. (4.9 to 1)
1)Sweet	Sweet with good baked taste.
2)Slightly sweetpotato taste	Sweet with giving some sweetpotato taste.
3)Off Taste	Giving off taste after eaten.
4)Burnt or Carmel Taste	Burnt or not good after taste
Color	Light brown to very dark brown. (4.9 to 1)
1)Light brown	Give uniform light brown color
2) Medium Brown	Give patches of light and dark brown
3) Brown	Uniform brown color.
4)Dark Brown	Very dark brown color
Overall Acceptability	Outstanding to Unacceptable (4.9 to 1)
1)Outstanding	4.0-4.9
2)Acceptable	3.0-3.9
3)Marginal	2.0-2.9
4)Unacceptable	1.0-1.9

Table 3. Physicochemical analysis of sweetpotato flour*

S. no	Constituents	Percentage (%)
1	Moisture	8.7±0.1
2	Starch	74.5±0.85 (dwb)
3	Reducing sugar	6.3±0.1 (dwb)
4	Total sugar	11.4±0.26 (dwb)
5	Ash	1.56 ±0.19 (dwb)
6	Protein	2.3±0.07 (dwb)
7	lipids	0.52±0.06
8	Falling number	134±1.0
9	Water absorption	172±1.5
10	Fiber	9.4±0.08

*Average of three reading
DWB = dry weight basis

Table 4. Effect of sweetpotato flour on odor intensity.

S. No	SPF: WF (%)	Mean panelist score (Odor intensity*)
1	00:100	1.3^{a}
2	20:80	2.5^{b}
3	40:60	2.6^{b}
4	60:40	3.1^{b}
5	80:20	4.0^{c}
6	100:00	4.2^{c}

The values denoted by different letters in the same column are significantly different ($p< 0.05$)
*average of ten panelist
1-1.9 = none, 2-2.9 = slight, 3-3.9 = moderate, 4-4.9 = strong

Adhesiveness, of dough's increased significantly (p < = 0.05) up to 340.15 at 80% sweetpotato flour addition, but at 100% sweetpotato flour the values decreased to 260.30. The cohesiveness increased significantly from 0.295 to 0.425 up to 40% sweetpotato flour addition and then decreased to 0.317 with increasing sweetpotato flour to 100%.

Quality characteristics of cookies

Physical characteristics of cookies

The spread value of cookies from different flours was not affected significantly (Table 8). The spread was greater 6.67 for cookies made from control, and decreased significantly with increasing the proportion of sweetpotato

Table 5. Effect of sweetpotato flour (SPF) on color values.

SPF:WF(%)	L*	a*	b*	Chroma	Hue angle
00:100	94.43^{d}	2.73^{a}	9.23^{a}	9.63^{a}	73.50^{c}
20:80	89.71^{c}	4.66^{b}	13.22^{b}	14.02^{b}	70.55^{c}
40:60	85.78^{b}	6.75^{c}	17.93^{c}	19.16^{c}	59.34^{b}
60:40	85.21^{b}	7.23^{c}	19.84^{c}	21.12^{c}	59.96^{b}
80:20	84.94^{b}	8.10^{d}	21.59^{d}	23.05^{d}	59.43^{b}
100:00	82.38^{a}	8.52^{d}	21.59^{d}	23.21^{d}	58.44^{a}

The values denoted by different letters in the same column are significantly different (p< 0.05)
*Average of three reading.

Table 6. Effect of sweetpotato flour (SPF) on Color values of cookies.

SPF: WF(%)	L*	a*	b*	Chroma	Hue angle
00:100	62.26^{e}	17.30^{d}	27.89^{d}	32.88^{d}	58.18^{d}
20:80	61.45^{d}	17.32^{d}	27.58^{d}	32.57^{d}	57.86^{c}
40:60	58.23^{c}	15.98^{c}	24.45^{c}	29.21^{c}	56.81^{c}
60:40	54.14^{b}	14.35^{bc}	20.36^{b}	24.91^{b}	54.80^{b}
80:20	53.89^{b}	13.47^{b}	19.04^{b}	23.32^{b}	54.71^{b}
100:00	48.43^{a}	11.03^{a}	13.49^{a}	17.43^{a}	50.70^{a}

The values denoted by different letters in the same column are significantly different (p< 0.05)
*average of three reading.

Table 7. Effect of different ratios of sweetpotato flour dough on Texture profile analysis.

SPF: WF (%)	Hardness Force (g)	Springiness (L2/L1) mm	Resilience A5/A4 g/s	Cohesiveness (*A2*/*A1*) g/s	Adhesiveness(g/s)
00:100	1105.0^{a}	0.364^{a}	0.151^{a}	0.295^{a}	19.31^{a}
20:80	1688.2^{b}	0.537^{c}	0.129^{c}	0.380^{b}	164.27^{b}
40:60	2649.1^{c}	0.522^{c}	0.132^{c}	0.425^{c}	209.69^{c}
60:40	2955.3^{c}	0.529^{c}	0.135^{b}	0.382^{b}	323.27^{e}
80:20	3684.7^{d}	0.443^{b}	0.138^{b}	0.365^{b}	340.15^{e}
100:00	4864.3^{d}	0.356^{a}	0.150^{a}	0.317^{a}	260.30^{d}

The values denoted by different letters in the same column are significantly different (p< 0.05)
*Average of three reading.

flour. There was significant decrease in thickness of cookies with marginal increases in sweetpotato flours. The density of the cookies, decrease gradually from 0.587 to 0.540g/cc and the decrease was significant. However, the fracture strength of cookies increased with addition of sweetpotato flour up to 40% and further decreased with increase in sweetpotato flour. This may be due to the higher fiber content in the flour. This indicated that the cookies became soft with increased sweetpotato flour content.

Sensory characteristics of cookies

The cookies formed with addition of 40% sweet potato flour got overall acceptability score of 3.6 which is very much acceptable to consumer (Table 9). Sensory evaluation shows that the cookies made from 100% sweetpotato flour was marginal acceptable with an overall score of 2.1.

The score of taste reduced significantly to 1.8. This is because of typical flavor component and caramalization of free sugar in sweetpotato flour during baking. However the texture of cookies made from 100% sweetpotato flour was tender and acceptable. The sensory score shows that sweet potato flour @ 40% is acceptable with reference to taste mouth feel, color and texture. Cookies can be made from sweet potato flour by addition of some flavor and improver.

Table 8. Effect of incorporation of sweetpotato flour into wheat flour on the physical characteristics of cookies.

SPF: WF(%)	Width(mm)	Thickness(mm)	Spread Factor	Density (g/cc)	Fracture Strength Force (g)
00:100	320^{d}	48^{e}	6.666^{e}	0.587^{e}	2632^{a}
20:80	310^{c}	47^{d}	6.595^{d}	0.560^{d}	3730^{d}
40:60	301^{b}	46^{c}	6.543^{c}	0.551^{c}	3800^{d}
60:40	293^{b}	45^{b}	6.511^{c}	0.549^{bc}	3722^{d}
80:20	280^{a}	44^{a}	6.363^{b}	0.543^{ab}	3535^{c}
100:00	275^{a}	44^{a}	6.150^{a}	0.540^{a}	3072^{b}

*The values denoted by different letters in the same column are significantly different (p< 0.05)
*average of three reading.

Table 9. Sensory characteristics of cookies made by adding various proportion of sweetpotato flour into wheat flour*.

SPF: WF (%)	Initial bite (Texture)	Mouth feel	Taste	Color	Overall
00:100	4.6^{d}	4.1^{d}	4.7^{c}	4.3^{c}	4.7^{d}
20:80	3.9^{c}	3.8^{cd}	3.7^{b}	4.1^{b}	3.9^{c}
40:60	3.7^{c}	3.5^{c}	3.5^{b}	4.0^{b}	3.6^{b}
60:40	3.4^{a}	2.3^{b}	2.1^{a}	3.7^{a}	2.7^{b}
80:20	3.2^{a}	1.9^{b}	1.9^{a}	3.7^{a}	2.3^{a}
100:00	3.2^{a}	1.3^{a}	1.8^{a}	3.6^{a}	2.1^{a}

* The values denoted by different letters in the same column are significantly different (p 0.05).

Conclusion

The out come of the present research can be used as valuable information for the development of high fiber low gluten cookies. Incorporation of 40% sweetpotato flour yielded approximately similar results compared with wheat flour cookies with improved nutritional value and texture.

Industrial relevance

This work showed the peculiar characteristics (water absorption capacity, moisture, protein, ash, lipids, crude fiber and falling number) of sweetpotato flour. The results obtained could be very valuable in decision making for industries that want to take nutritional advantage of sweetpotato flour as alternative or supplement to cereal flours. Sweetpotato flour could be useful in the manufacture of highly nutritious cookies.

REFERENCES

AACC (1983) Approved Methods, 8th ed. St. Paul, MN: *American* Association of Cereal Chemists

AACC (1995) Approved methods of the *American Association of Cereal Chemists*. 10th ed. Method 44-15A, 44-13, 08-01, 30-10 and 32-10.. The Association: St. Paul, MN.

Abd El, Moniem GM (1994) Mathematical models for maximum improvement of in vitro protein digestibility of high dietary fiber cookies, Nahrung. 38 (1): 32-37

Anderson RA, Conway HF, Pfeifer VF, Griffin EL (1969). Gelatinization of corn grits by roll and extrusion cooking. Cereal Science Today. 14: 4-6.

AOAC (1981). Official methods of analysis of AOAC. 14th ed. Washington, Association of Analytical Chemists.

Bloksma AH, Bushuk W (1988). Rheology and chemistry of dough. In: Pomeranz Y (ed) Wheat chemistry and Technology, 3rd edn. *American Association of Cereal Chemists*, Minnesota. pp. 131–217

Chiappe L, Lopez PE, Villagarcia M (1984). Yield and flour production of twelve white sweet potato cultivars for industrial use. In: *Proceedings of Sixth Symposium of the International Society for Tropical Root Crops* (edited by J.E. Wenham). Lima, Peru: Faculty of Agriculture, National Agrarian University. pp. 587- 589.

Collins M (1989).Economic Analysis of Wholesale Demand for Sweetpotatoes in Lima, Peru, M.Sc. Thesis, Department of Agricultural and Resource Economics, University of Florida, Gainesville, USA.pp.1-164.

El-sahy KM, Siliha H (1988). Use of sulphite treated sweet potato flour in manufacturing of wheat bread. Getreide Mehl und Brot. 42 (7): 215-217

Faridi H, Faubion JM (1986). Dough rheology: its benefits to cereal chemists. In: Faridi H, Faubion JM (eds) Fundamentals of dough rheology. American Association of Cereal Chemists, Minnesota. pp. 1-9.

Hagenimana V, Carey E, Gichuki ST, Oyunga MA, Imungi JK (1992) Changes in carotenoid content after drying and processing sweetpotato products. Ecological Food Nutrition, 37: 450-473

Hamed MGE, Siliha H, Sandy SK (1973). Preparation and chemical composition of sweet potato flour. Cereal and Bakery Products. 50 (2): 133-139.

Horton D, Fano H (1985). Potato Atlas, International Potato Center (CIP), Lima, Peru. p. 136.

Lizado MLC, Guzman MP (1982). Development of new products using

sweetpotato flour Home Econ. J. 10(1): 62.
Manohar RS, Haridas R. (1999). Effects of water on the rheological characteristics of biscuit dough and quality of biscuits. *Eur Food Res Technol* (209):281-285
Owori C, Hagenimana V (2000). Quality evaluation of sweetpotato flour processed in different agro-ecological sites using small scale
processing technologies. African Potato Association Conference Proceedings. 5: 483-490.
Purcell AE, Later WL, Lee Ml (1980). Analysis of the volatile constituents of baked, “Jewel” Sweetpotato. J. Agric. *Food* Chem (28): 939-941.
Ranganna S (1999). Handbook of analysis and quality control for fruits and vegetable products. Tata McGraw Hill Publication, 2nd ed. New Delhi. pp. 1-15
Tilman JC, Colm MOB, Denise MC, Anja D, Elke KA (2003). Influence of gluten free flour mixes and fat powder on the quality of gluten free biscuits Eur Food Res. Technol 216: 369-376
Ulm SG (1988). The Effect of Storage Conditions on Selected Quality Attributes of Sweetpotato Flour, Thesis of the University of Tennessee, Knoxville. p. 7-26
Van Hal M (2000). Quality of sweetpotato flour during processing and storage. Food Rev. Inter. 16: 1-37.
Woolfe JA (1992). Sweetpotato: An Untapped Food Resource, Cambridge University Press, Cambridge, 292-389.