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Utilization of biowaste from commercial lotus cultivation by incorporating rhizome flour for low glycaemic cookies

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Abstract

Lotus rhizome is a huge biowaste from the commercial lotus flower cultivation and its disposal is a serious issue. Physico-chemical analyses of fresh lotus rhizomes were performed and alternative use of lotus rhizomes in commercial cookie making industry was experimented. Cookies were prepared by supplementing different proportions of lotus rhizome flour to wheat flour (10-100%) and their nutritional, sensory, antioxidant properties and glycaemic indices were studied. Composition analysis had shown that the lotus rhizomes are good source of starch, carbohydrates, protein, fat, dietary fibre, vitamin C, calcium, iron, phosphorus and potassium. Cookies prepared from 10% lotus rhizome flour and 90% wheat flour was most acceptable in sensory evaluation and richer in minerals, unsaturated fatty acids, flavonoids, phenols and antioxidant value. The glycaemic index and total fat content were lower in lotus rhizome flour incorporated cookies, pointing that the biowaste from lotus cultivation can be efficiently used in biscuit industry.

Keywords: Edible flowers, Food fortification, *Nelumbo nucifera*, Organic waste, Value addition, Waste utilization.

Introduction

Blossoms of lotus (*Nelumbo nucifera*, Nymphaeaceae) are sacred to Buddhists and Hindus due to its magical healing capabilities (Kandeler and Ullrich, 2009). Since ancient times, lotus has extensive spread through Egypt, Asia and Persia which played a role in symbolism for over 4000 years (Wang and Zhang, 2005; Mukherjee et al., 2009).

In India alone, lotus is commercially cultivated in an area of 0.2 million acres, leading to nearly 1.5 million tonnes of rhizome waste in every season. Unless the exhaustive rhizome mat is cleared in every season, there will be a drastic reduction in the number of flowers in the subsequent crop.

The lotus rhizome is shown to have many medicinal qualities. Antidiabetic effect of the ethanolic extract of the rhizome is demonstrated in diabetic rats (Mukherjee et al., 1995) and this is due to the anti-diabetic compound tryptophan in rhizome nodes (Lee et al., 2001). The condensed tannins present in lotus rhizome can relieve hepatic steatosis by suppressing the lipogenic enzyme activity in the liver of diabetes mice (Tsuruta et al., 2012).

Lotus rhizomes are taken as raw in salad preparations, but mostly in cooked form in Chinese and Japanese cuisines. Rhizomes are cooked in various forms as fried and boiled as soup with pork, steak, or chicken or other kinds of meats. They are also steamed with rice and soaked in syrup or pickled in vinegar (Sheikh, 2014). Lotus rhizomes

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contain mild sweet flavour which makes it suitable to be absorbed in various foods (Vora and Srinivasan, 2016). They also possess strong antioxidant effects which can be utilized in processed meat products to improve functional and quality characteristics (Jung et al., 2011).The lotus rhizome flour contains good amount of dietary proteins and sugars which can be applied in food and bakery products. Good oil absorption capacity, water holding capacity and swelling capacity make it suitable in pudding foods such as soup, gravies and baked goods. Lotus rhizome flour has least gelation concentration with higher gelatin that can be used as adjuvant in food industries. Lotus rhizome flour also contains good froth stability and foaming capacity which is suitable to formulate food products. High bulk density makes the flour useful in packing and in the composing of nutrient dense weaning food (Shad et al., 2011). Lotus rhizome is widely favoured by Asian people because of its hard, crispy texture, special flavour and mouth feel (Li et al., 2017).

Even with all these favourable reports, this biomass continues as an unresolved issue for the growers. Identification of platform that commercially uses this biomass in high quantity can only solve this issue. Development of composite flour bakery products with nutraceutical properties is the latest trend in bakery industry. Nutritious and medicinally valuable plant foods are important and hence, enrichment of cereal products with under-utilized components such as lotus rhizome will be an interesting choice. Cookies are consumed all over the world as a snack and considered as source for delivering important nutrients to the population (Chinma and Gernah, 2007; Ubbor and Akobundu, 2009). This study details the physico-chemical properties of lotus rhizomes, incorporation of wheat cookies with rhizome flour and discusses the enhanced nutritional and medicinal properties of the cookies. The study shows that this methodology is promising to solve the biowaste issue in commercial lotus cultivation.

Materials and Methods

Fresh rhizomes were collected from farmers' fields of Palakkad and Malappuram districts of Kerala state, India.

Analysis of physico-chemical qualities of rhizomes
Moisture content, total starch, carbohydrates, fibre, total ash, proteins, fat, vitamin C, calcium, iron, phosphorus and potassium in fresh rhizomes were analysed using standard procedures (Sullivan and Carpenter, 1993). Analyses were replicated three times.

Standardisation of lotus rhizome cookies
Cookies were prepared using rhizome flour and wheat flour in varying levels, as per the standard procedure (Eswaran, 1994). The treatment T_0 was control with 100 per cent refined wheat flour and T_1 had 100 per cent lotus rhizome flour (LRF). The treatments T_2 to T_6 had 80, 60, 40, 20 and 10 per cent LRF combined with 20, 40, 60, 80 and 90 per cent wheat flour, respectively. Ingredients mentioned in Fig. 1 were mixed well to get a dough with desirable consistency. It was then covered with moist cloth and kept for proofing for 2 h and re-kneaded before moulding to shapes. It was then moulded and kept for baking at 150° C for 20 min.

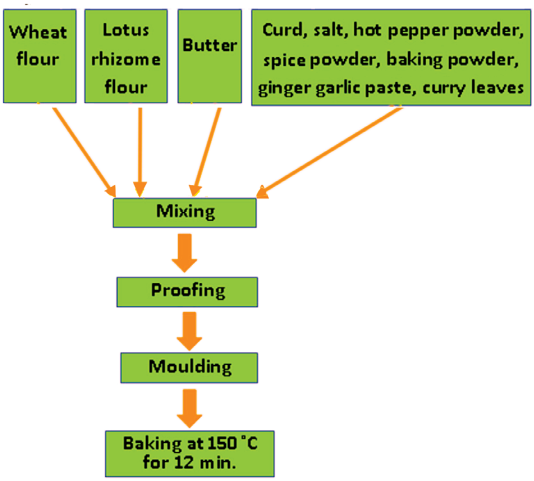

Figure1. Flow chart for the preparation of cookies

Analysis of cookies

Organoleptic evaluation

Organoleptic qualities were evaluated by score card method, using nine-point hedonic scale by a panel of 15 selected judges (Swaminathan, 1974). To choose the team of judges aged between 18 to 35 years, a series of organoleptic trials were conducted at laboratory level, using simple triangle test (Jellinek, 1985). Six quality parameters, appearance, colour, flavour, texture, taste and overall acceptability, each on a nine- point hedonic scale, were presented in the score card. From the scores, best treatment was decided by Kendall's coefficient of concordance.

Physico-chemical qualities

Physico-chemical qualities of the cookies including moisture content, total carbohydrate, protein, total fat, fibre, total ash, calcium, iron, potassium, sodium, free fatty acids, total flavonoids, total phenols, peroxide value and iodine value, were assessed using the standard procedures (Sullivan and Carpenter, 1993).

Antioxidant activity

Antioxidant capacity of the cookies extract was computed using 1'1-diphenyl-1-picryl hydrazine (DPPH) spectrometric assay (Blois, 1958). To various concentration of the sample, methanolic solution containing DPPH radicals (0.1mM) was added and stirred strenuously. The reaction mixture was allowed to stand for 30 min. in dark and absorbance was read at 517 nm in a spectrophotometer. The antioxidant activity (%) was calculated as per cent inhibition of free radical

$$= \frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Control}} \times 100$$

The sample concentration providing 50 per cent inhibition (Inhibitory concentration - IC_{50}) was calculated from the graph of radical scavenging activity percentage against sample concentration (gallic acid was used as standard).

Glycaemic index

Five healthy individuals were identified through glucose tolerance test. The subjects stopped all medication at least 3 days prior to the test and maintained 8 h of fasting. For each subject, fasting blood glucose and postprandial glucose level after consuming the lotus rhizome based cookies, were recorded using a glucometer and compared with the control. The blood glucose levels were recorded at specific time intervals of 30 min. up to 2 h after the food load. An equivalent quantity of test food was taken in comparison with glucose of 75 g. Glycemic index of the cookies were computed as the ratio of incremental area under the 2 h plasma glucose curve after consuming 75 g of carbohydrate from test food and the incremental area under the 2 h plasma glucose curve after consuming 75 g of carbohydrate from glucose (Srilakshmi, 2011).

Results and Discussion

Nutritional composition of lotus rhizome

The constituents of fresh rhizomes, moisture, starch, carbohydrates, protein, fibre, vitamin C, total ash, calcium, iron, phosphorus, sodium and potassium, are presented in Table 1. The mean moisture, starch, carbohydrate, protein, fat, crude fibre and total ash contents (%) in the fresh rhizomes were 72.14, 10.05, 16.03, 2.60, 0.10, 4.20, 1.18, respectively. Vitamin C, calcium, iron, phosphorus and potassium contents were 38.0, 40, 1.07, 58.0 and 450.0 mg/ 100 g.

Table 1. Composition of fresh rhizome of *Nelumbo nucifera* (mean values over 3 replications)

Component	Content (in 100 g)
Moisture (%)	72.14
Starch (g)	10.05
Carbohydrates (g)	16.03
Protein (g)	2.60
Fat (g)	0.10
Fibre (g)	4.20
Vitamin C (mg)	38.00
Total ash (g)	1.18
Calcium (mg)	40.00
Iron (mg)	1.07
Phosphorus (mg)	58.00
Potassium (mg)	450.00

The mean moisture content of 72.14% in the fresh rhizomes was comparable with that in the previous reports, 75.40 and 77.58% (Li et al., 2017; Khattak and Simpson, 2009). Moisture content of 83.80% reported by Mukherjee et al. (2009) is high when compared to the present results. Starch content of 10.5% was also on par with the reported levels of 9.25 (Mukherjee et al. 2009) and 15.00% (Syed et al., 2012). Lotus starches are amylose rich (21.16 %), possess good clarity and gel strength (Geng et al., 2007) and hence could be used as an additive in food industry for imparting better texture and consistency and also as functional ingredients such as thickener, stabilizer and gelling agent. The carbohydrate content of rhizomes was 16.03%, similar to previous reports of 16.60 and 16.02% (Khattak and Simpson, 2009; Sheikh, 2014). Protein content of 2.60% was close to the reported levels of 2.41 and 2.70% (Mukherjee et al., 2009; Khattak and Simpson, 2009). Protein content of 1.70% reported by Paudel and Panth (2015) appears lower. Fat content of 0.10 % was similar to the previous reports of 0.11 and 0.07% (Mukherjee et al., 2009; Sheikh, 2014).

Crude fibre content of 4.20% found in this study appears slightly higher than the previous reports of 3.10 (Sheikh, 2014), 1.63 (Khattak et al., 2009) and 0.80% (Paudel and Panth, 2015). This shows that the fibre content of lotus rhizomes varies with accessions. Total ash in rhizomes was 1.18%, against 1.10, 1.22 and 1.04% reported previously (Mukherjee et al., 2009; Khattak et al., 2009, Faruk et al., 2012).

Vitamin C content in the rhizome was 38 mg/ 100 g which is higher than the previous reports of 27.4 mg (Sheikh, 2014) and 28.0 mg (NIN, 2002). Vitamin C content of lotus rhizomes varies with accessions, soil and edaphic factors. Calcium, iron, phosphorus and potassium contents (40, 1.07, 58.0 and 450.0 mg/ 100g) were higher or nearly similar compared to those reported (27.4, 0.9, 78.0 and 363 mg, respectively) (Sheikh, 2014).

Organoleptic qualities of lotus rhizome cookies

Organoleptic qualities of the cookies were scored based on their mean scores using Kendall's (W) coefficient of concordance (Table 2). Mean score for the appearance varied from 8.44 to 6.47 with a mean rank score in the range of 6.27 to 1.33. The cookies prepared with the combination of 10% lotus rhizome flour and 90 %wheat flour (T_6) and control had a maximum score of 8.44 with the highest mean rank scores of 6.07 and 6.27, respectively. All other treatments got scores above 6.0.

For colour, cookies prepared with 10 % lotus rhizome flour obtained the highest mean score of 8.71 and mean rank score of 6.97 (Fig. 2). The maximum mean scores for flavour (8.18) and texture (8.33) with the mean rank scores of 6.57 and 6.43, respectively, were obtained by T_6. Mean score for taste was highest in cookies prepared with treatment T_6 (8.53) followed by T_0 (8.49). The mean score for overall acceptability of cookies prepared with treatment T_6 (8.45) was highest with a mean rank score of 6.53.

Table 2. Mean scores for the organoleptic qualities of cookies prepared with lotus rhizome flour and wheat flour in comparison with control

Treatments	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability	Total score
T_0 (100% W)	8.44(6.27)	8.04(5.87)	8.11(6.33)	8.38(6.57)	8.49(6.37)	8.38(6.37)	49.84
T_1 (100% L)	8.16(5.40)	7.40(3.90)	7.4(4.53)	7.16(3.87)	7.04(3.53)	7.44(4.27)	44.60
T_2 (80% L +20% W)	7.71(4.00)	6.80(2.43)	6.76(3.07)	7.00(3.50)	6.89(3.27)	6.82(2.50)	41.98
T_3 (60% L+40% W)	6.78(2.00)	6.82(2.53)	6.13(1.40)	6.78(2.40)	6.62(1.97)	6.58(1.87)	39.71
T_4 (40% L+60% W)	6.47(1.33)	6.42(1.30)	6.38(2.17)	6.87(2.60)	6.71(2.33)	6.49(1.80)	39.34
T_5 (20% L+80% W)	7.13(2.93)	7.73(5.00)	7.07(3.93)	6.84(2.63)	7.11(4.00)	7.69(4.67)	43.57
T_6 (10% L+90% W)	8.44(6.07)	8.71(6.97)	8.18(6.57)	8.33(6.43)	8.53(6.53)	8.45(6.53)	50.64
Kendall's (W) value	0.877**	0.932**	0.865**	0.727**	0.757**	0.898**	

(Value in parentheses is mean rank score based on Kendall's W, replications-3, ** Significant at 1% level, L- Lotus rhizome flour, W- Wheat flour)

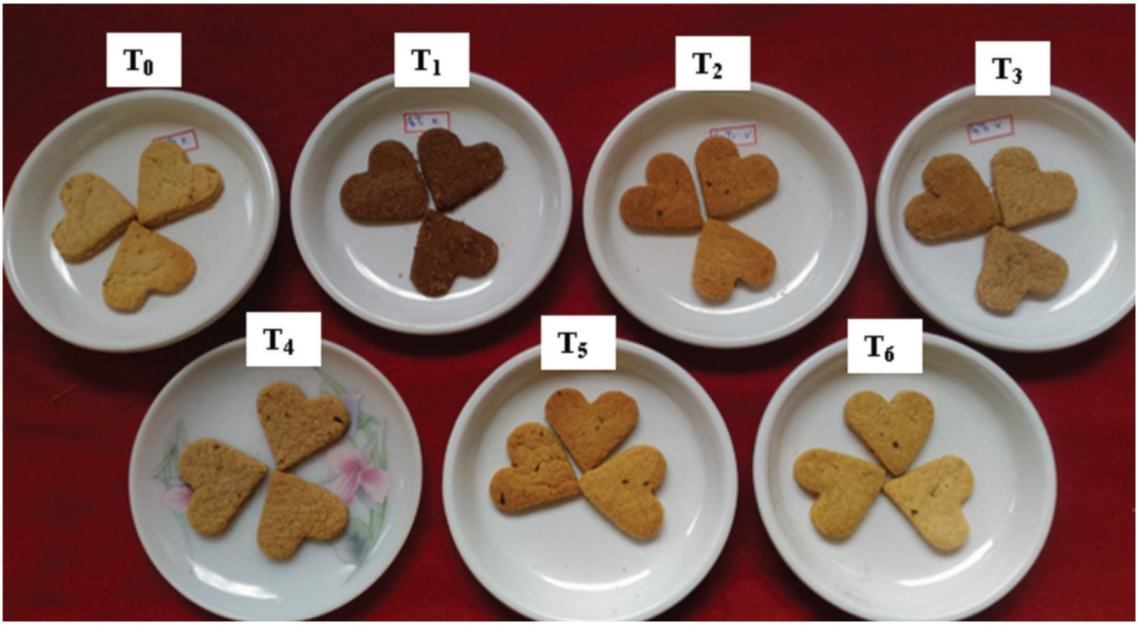

Figure 2.Combinations of treatments for lotus rhizome flour and wheat flour incorporated cookies (T_0-100% WF control, T_1-100% LRF, T_2-80% LRF + 20% WF, T_3-60% LRF + 40% WF, T_4-40% LRF + 60% WF, T_5-20% LRF + 80% WF, T_6-10% LRF + 90% WF)

Highest organoleptic score was obtained by T_6, followed by T0. Cookies made of cent percent rhizome flour (T_1) received score above 7, indicating a good sensory acceptability. All other treatments got scores above 6, showing that they had good sensory characteristics. Cookies from T_6 were selected for further nutritional analyses.

Cookies prepared with the combination of 10 % lotus rhizome flour and 90 % wheat flour and control had the maximum scores for the organoleptic parameters. High scores earned by the other treatments show their acceptable sensory characteristics. Hence fortifying cookies with lotus rhizome flour increases the sensory and nutritional qualities. In bread sticks blended with lotus rhizome flour, up to 15% blending was possible with no reduction in sensory acceptability (Thanushree et al., 2017). Similarly, organoleptic evaluation of toffee-flavoured milk shake having lotus rhizome as the major ingredient, has shown it as a promising strategy to include lotus rhizome in the daily diet (Vora and Srinivasan, 2016). Lotus rhizome flour was also incorporated up to 3 % in cooked sausages, which showed positive impacts on cooking losses, texture and thiobarbituric acid reactive substances value, with no adverse impacts on its overall acceptability (Ham et al., 2017).

Physico-chemical and nutritional qualities of cookies

Nutritional constituents and antioxidant properties of 10% lotus rhizome flour incorporated wheat cookies and 100% wheat flour based cookies are compared in Table 3. Moisture content of rhizome flour incorporated cookies was 4.23%, slightly lower than 4.57% in wheat flour based cookies. The carbohydrate content of the rhizome flour incorporated cookies was 48.12%, against 51.89% in wheat cookies. Rhizome flour incorporated cookies wheat cookies had comparable protein content, at 10.03 and 11.29%, respectively. Total fat content of the rhizome incorporated cookies and wheat cookies were 25.65 and 33.89%, respectively. The fat content in the cookies prepared in this study is comparable with that in the cookies available commercially. Even with 25.65% fat these cookies are considered healthier due to their antioxidant

*Table 3.*Nutritional composition and antioxidant capacities of cookies with 10% lotus rhizome flour and 90% wheat flour and cookies with 100% wheat flour (mean ± SD, *n*-3)

Parameter	Content	
	Cookies with 10% lotus rhizome flour and 90% wheat flour	Cookies with 100% wheat flour
Moisture (%)	4.23 ± 0.02	4.57 ± 0.02
Carbohydrates (%)	48.12 ± 7.53	51.89 ± 5.88
Protein (%)	10.03 ± 0.03	11.29 ± 0.10
Fat (%)	25.65 ± 4.23	33.89 ± 5.01
Fibre (%)	2.44 ± 0.97	0.77 ± 0.30
Total ash (%)	3.37 ± 0.01	3.55 ± 0.02
Free fatty acids (%)	-	0.03 ± 0.01
Potassium (mg)	280.11 ± 2.11	123.2 ± 1.86
Sodium(mg)	12.32 ± 0.07	8.85 ± 0.31
Iron (mg)	3.33 ± 0.03	1.86 ± 0.08
Calcium (mg)	30.42 ± 2.02	24.44 ± 1.89
Iodine value (mg/ kg)	90.21±3.28	42.41 ± 2.11
Peroxide value (meq/ kg)	-	-
Total phenol (mg/ 100g)	138.50 ± 1.84	97.34 ± 2.87
Total flavonoid (mg/ 100g)	70.42 ± 5.46	62.89 ± 3.86
Antioxidant capacity (% inhibition of free radicals)	50.27 ± 5.66	19.34 ± 1.50

potential and low glycaemic index. Rhizome flour incorporated cookies had considerably higher level of total fibre content, with 2.44% compared to 0.77% in wheat cookies. Total ash content in rhizome flour incorporated cookies and wheat cookies were comparable, at 3.37 and 3.55%, respectively.

For all the minerals, lotus rhizome flour incorporated cookies were richer than wheat cookies. The calcium, iron, sodium and potassium contents in rhizome incorporated cookies were 30.42, 3.33, 12.32 and 280.11 mg/ 100 g compared to 24.44 , 1.86, 8.85 and 123.21 mg/ 100 g in wheat cookies. Free fatty acids were not detected in rhizome incorporated cookies where as, wheat cookies had them at 0.03%. Iodine value of the rhizome flour incorporated cookies was 90.21 g/ 100 g against 42.41 in wheat cookies, clearly showing that the former is healthier.

The moisture content in the cookies was higher than the reported level of 2.58 - 2.62% in lotus rhizome based breadsticks (Thanushree et al., 2017). Cookies based on water chestnut and cassava flour had 5.63% (Bala et al., 2015), flax seeds flour (10%) based had 6.63 (Masoodi and Bashir, 2012) and dry fructo-ligosaccharide enriched had 2.2 - 2.6% (Handa et al., 2012) moisture levels.

Carbohydrate content in rhizome flour incorporated cookies was lower than that in wheat cookies. Millet flour blended and fenugreek seed flour blended cookies had 60.2 - 66.5, 60.0 - 62.0% carbohydrates, respectively (Eneche, 1999; Hooda and Jood, 2005). The protein content was similar to 11.6 - 14.2% in cookies fortified with 20% defatted mustard flour (Tyagi et al., 2007). The protein content of cookies based on tannia flour was 12.25% (Asumugha and Uwalaka, 2000) whereas, it was 10.84 in cookies prepared with 10% flax seeds flour (Masoodi and Bashir, 2012). The fat content was much higher than 6.31 - 6.87% reported in lotus rhizome based breadsticks (Thanushree et al., 2017). Cookies prepared from water chestnut and cassava flours had 24.87% fat (Bala et al., 2015) but in millet flour blended (Eneche, 1999) and amaranth flour blended (De la Barca et al., 2010) cookies, it was only 17.1-18.1 and 15.45%, respectively.

Rhizome flour incorporated cookies had considerably higher level of total fibre content. Fibre content of 3.19 and 4.63% were reported in cookies prepared using 20% defatted wheat germ and swamp taro, respectively (Arshad et al., 2007, Pahila et al., 2013). Cookies fortified with 20% defatted mustard flour had only 0.39-0.4% fibre (Tyagi et al., 2007). Lesser fibre content in mustard seeds compared to that in rhizomes may be the reason for the lower fibre content in cookies. The fibre content of bread increased from 1.15 to 2.20% with increase in the level of taro flour (Ammar et al., 2009).

Total ash content in rhizome flour incorporated cookies and wheat cookies were comparable. This is higher compared to 1.50, 1.27, 1.81, 2.64 and 1.79% reported in cookies prepared using 20% defatted wheat germ and swamp taro (Arshad et al., 2007), plantain flour (Oyeyinka et al., 2014), swamp taro flour (Pahila et al., 2013), flax seeds flour (Masoodi and Bashir, 2012) and amaranth flour (De la Barca et al., 2010), respectively.

Compared to wheat cookies, lotus rhizome flour incorporated cookies were richer for all the minerals estimated. Calcium, iron, sodium and potassium levels reported in tannia flour based cookies were 42.33, 2.35, 15.35 and 237.3 mg/100g, respectively (Anaveri, 2016). Baked products enriched with different types of flour, other than wheat, are reported to have better mineral content (Hooda and Jood, 2005; Chinma et al., 2012; Alcantara et al., 2013; Oyeyinka et al., 2014).

Even though the wheat cookies had 0.03 % free fatty acids, it was not traceable in rhizome incorporated cookies. Tannia flour based cookies are reported to have no free fatty acids (Anaveri, 2016) whereas, wheat and coconut cookies had 0.18 and 0.037 %, respectively (Dhankhar, 2013). Quantity of free fatty acids/ trans-fatty acids in cookies depends on the type of processes and the raw material (Stroher et al., 2012).

Iodine value of the rhizome flour incorporated cookies was more than double compared to wheat cookies. Iodine value is the level of unsaturated fatty acids in the products which depends on the quantity of fat used in the product. This has clearly shown that the lotus rhizome flour incorporation makes the wheat cookies much healthier. The iodine values of the tannia flour based and wheat germ oil based cookies were 115.54 and 107 g per 100 g, respectively (Anaveri, 2016; Arshad et al., 2008). Peroxides were not detected in all the cookies as in case of potato flour based cookies (Seevaratnam et al., 2012). Peroxide values of cookies prepared using different blends of palm oil and cotton seed oil are reported to be 0.34-0.37 meq/ kg (Waheed et al., 2010). Cookies prepared with complete fat replacement with black cumin oil had lower peroxide value of 0.189 meq/ kg (Saeedi and Ahmadg, 2011).

Antioxidant activity of cookies

Antioxidant properties of plants could be attributed to vitamin C, β-carotene, and phenolics including flavonoids and phenylpropanoids. Total flavonoids in the lotus rhizome flour based cookies was 70.42mg/100 g compared to 62.89 in wheat cookies. The antioxidant activity of lotus rhizome flour based cookies was much higher at 50.27%, compared to that of wheat cookies at 19.34%. This was already evident from the flavonoid and phenol contents in both.

Antioxidant properties of plant products is resulted mainly by vitamin C, β-carotene, and secondary metabolites including flavonoids and phenylpropanoids. Interestingly, lotus flour incorporation has enhanced nearly tripled the antioxidant potential of the cookies. The high level of flavonoids and phenols in lotus rhizome has contributed to this. Flavonoid contents of lotus leaves in ethanolic and methanolic extracts were 69.5 and 106.9 mg kaempferol eq/g (Choe et al., 2010). Flavonoid content of elephant foot yam and tannia flour based cookies was 78.59-84.39 mg/100 g (Anaveri, 2016) whereas it was 26.18-37.64 and 14.57-19.53 mg/ 100 g in cookies prepared using pomegranate peel powder and pomegranate juice, respectively (Paul and Bhattacharyya, 2015). Total phenol contents in methanol and ethanol extracts of lotus rhizome were 25.49±1.15 and 17.6±3.80 mg GAE/ g of dry sample, respectively (Ullah et al., 2018). Total phenol content of lotus rhizome based cookies was 138.50 mg/100 g against 97.34 in wheat cookies. Similarly, the total phenol content in cookies prepared by incorporating pomegranate peels was 90.7 mg GAE/100 g (Ismail et al., 2014).

Methanol and acetone extract of lotus rhizome are reported to have the DPPH scavenging activities at 66.7 and 133.3 mg/L, respectively (Yang et al., 2007) whereas, hydro-alcoholic extract of lotus seed had strong free radical scavenging activity with IC_{50} values of 6.12±0.41 mg/ mL in the DPPH assay and 84.86±3.56 mg/mL in the nitric oxide assay (Rai et al., 2006). Antioxidant activities of cookies prepared using pomegranate peel powder and pomegranate juice were 39.18-118.23 and 60-102 mg/100 g, respectively (Paul and Bhattacharyya, 2015) whereas it was 44.16% in flaxseed flour incorporated cookies (Kaur et al., 2017).

Glycaemic index of cookies

The glycaemic index of lotus rhizome flour incorporated cookies (50.51) was lower than that of cookies made from wheat flour (65.25). This has clearly shown that the lotus rhizome flour incorporated cookies can be recommended for the people with diabetes.

The glycaemic index of lotus rhizome flour incorporated cookies was evidently lower compared to that in wheat cookies. The chemical properties of the starches in tubers and rhizomes might be imparting a reduction in the glycaemic index. Ten different starches isolated from *Dioscorea* had low glycaemic indices ranging from 44.11 to 50.05 (Jiang et al., 2013). Glycaemic indices in lotus seed porridge and barley porridge were 56.21 and 65.21, respectively, with 94.40 in control wheat bread (Ma et al., 2018). Similarly, barnyard millet based vermicelli had a glycemic index of 55.65 compared to 74.89 in wheat based vermicelli (Chandraprabha, 2017). Low glycaemic index foods are good for diabetics to maintain low blood sugar levels (Salmerón et al., 1997).

Economic potential

This study shows that wheat cookies fortified with 10% lotus rhizome flour will be better nutritious, organoleptically acceptable and possess higher antioxidant and lower glycaemic values. Fresh rhizomes contain 72.14% moisture and hence, to prepare 100 g of fortified cookies, nearly 36 g of fresh rhizome has to be used. India is currently the world's largest biscuit and cookie consuming nation, with the production nearing a million tonne. The industry had grown at 14 per cent till the financial year 2018-19. This shows that in Indian alone, the cookies industry is capable to accommodate nearly 0.40 million tonnes of lotus rhizome waste, worth 0.35 billion USD.

Rhizome biomass from the commercial lotus cultivation is a serious issue demanding immediate attention. Burial and partial composing are the only strategies for the disposal of this waste. New incorporation strategies could add demand and value to this. The physico-chemical analyses of lotus rhizome had shown that they are rich in proteins, dietary fibre and minerals. Cookies prepared by substituting wheat flour with lotus rhizome to the tune of 10% had resulted cookies with better organoleptic qualities. Comparative analysis had shown that these cookies are richer in minerals, dietary fibre, flavonoids, phenols and possess better antioxidant potential. The fat content and glycaemic index were lower compared to the wheat cookies, making it better for hypercholesterolemic and diabetic people. Thus, lotus rhizome, a waste from the lotus flower cultivation, could be utilized as a supplement in industry, to prepare nutrient rich and diabetic-friendly cookies. Approximately 0.4 million tonnes of lotus rhizomes could be utilized in the biscuit and cookie industry in India alone.

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