Processing, physico-chemical, sensory and nutritional evaluation of protein, mineral and vitamin enriched peanut *chikki* - an Indian traditional sweet

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Abstract *Chikki*, a popular Indian traditional sweet snack prepared from peanut was enriched with protein, minerals and vitamins by incorporating soy protein isolate, calcium carbonate, ferrous fumarate, vitamin A and folic acid to meet the growing demand for health foods. The enriched nutra *chikki* was evaluated for physico-chemical characteristics such as moisture, texture, peroxide value (PV), fatty acid composition in comparison with control peanut *chikki*. Nutra *chikki*, which had initial moisture content of 2–3%, did not alter much up to 60 days of storage at 27 °C and 37 °C. PV increased gradually at 27 °C, whereas at 37 °C, it was higher. Hardness of nutra *chikki* did not change significantly when stored at 27 °C up to 105 days, but at 37 °C a gradual increase in hardness was observed after 45 days. These results of nutra *chikki* were similar and comparable with those of control *chikki*. Nutra *chikki* had 18% protein, 20% fat, 6.42% Ca, 1.7% Fe, 4000 µg vitamin A and 2660 µg folic acid. Protein digestibility corrected amino acid score of nutra *chikki* was 0.78 whereas that of control *chikki* was 0.73. The fatty acid composition of control and nutra *chikki* was same as both contain peanuts as oil source. The formulation and process parameters for preparation of protein, mineral and vitamin enriched peanut *chikki*, were standardized. The storage stability and quality parameters of enriched *chikki* were comparable with those of control *chikki*.

Keywords Peanut *chikki* · Fortified *chikki* · Protein enriched *chikki* · Processing · Sensory evaluation

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Introduction

Consumers are increasingly conscious about health and have begun to look at the nutritional benefits of food, disease prevention and health promoting compounds in many foods. According to market statistics, the global functional food and nutraceuticals market is increasing with a compound annual growth rate (CAGR) of 7.4% that is outpacing the traditional processed food market and is expected to reach USD 176.7 billion in 2013 (Ahmad et al. 2011). Canada is emerging as a leading world supplier in this growing market and the country boasts more than 300 companies - from small start-ups to multinational enterprises - many that are internationally recognized for the incorporation of bioactive ingredients, such as soluble fibre from oats, barley and pulses, omega-3 fatty acids from fish and flax oil, unsaturated fatty acids from canola oil, plant sterols and stanols from vegetable oils, and protein from soy bean. Industry is also putting efforts to incorporate functional ingredients into food products, such as probiotic bacterial cultures, prebiotics (e.g. fructo-oligosaccharides) from corn, bio-actives concentrated from berries and flax, and novel fibres from pulses etc (Ahmad et al. 2011).

Peanut *chikki*, also called as peanut brittle in western countries is a ready to eat traditional sweet snack, which is popular throughout the country and consumed by all the sections of the population. The main ingredients used in *chikki* preparation include peanut, cane sugar or jaggery (gur) and liquid glucose (Vidyasagar et al. 1964). Puffed Bengalgram, sesame, puffed rice, coconut flakes (Manay and Shadaksharswamy 1995), sunflower kernels (Clandinin 1978) and soybean have also been used as ingredients either individually or in combination. Vidyasagar et al. (1964) have reported the preparation of groundnut candy

and bar using sucrose, liquid glucose, roasted groundnuts, roasted split puffed Bengalgram, roasted white sesame (*Sesamum indicum* L.) seeds and pineapple essence. Preparation of *chikki* based on sesame and peanuts, roasted Bengalgram dhal and jaggery has been reported by Prasad et al. (1995). Chahal and Sehgal (1996) have reported the development and nutritional evaluation of groundnut *chikki* and sesame-groundnut *chikki*. Gupta et al. (2007) studied the textural characteristics of sunflower-sesame kernel *chikki*.

The functional food industry in India is strong and is a growing force in the international health foods market. The health and wellness foods market is currently estimated to be in the vicinity of USD 1.6 billion and expected to reach USD 7.5–10 billion by the year 2015 (Palthur et al. 2009). In order to provide health benefits beyond basic nutrition, peanut *chikki*, a popular Indian traditional sweet snack, was taken to enrich with essential nutrients such as protein, Ca, Fe, vitamin A and folic acid so as to provide part of RDA to the targeted population. The RDA requirements for 10–15 years age group are: Ca (600 mg), Fe (28 mg) and protein 55 g.

The primary objective of the present study was to develop a protein and mineral enriched peanut *chikki* and to evaluate its nutritional and other physico-chemical characteristics and acceptability.

Materials and methods

Peanuts and jaggery were procured from local market, soy protein isolate (SPI) was procured from DuPont, Mumbai. Calcium carbonate (CaCO_3), ferrous fumarate ($\text{C}_4\text{H}_2\text{FeO}_4$), vitamin A and folic acid (Vitamin B9) were procured from Hexagon Chemicals Ltd., Nasik, India.

Roasting of peanuts The peanut seeds were roasted to golden brown colour (120 ± 10 °C) in a drum roaster for 20 min. The roasted peanuts were dehusked, degermed and crushed into small bits in a domestic mixer and passed through 3000 μ mesh sieve, which were used in *chikki* formulation.

Process for the preparation of nutra *chikki* The traditional method of *chikki* preparation was followed and the process was same for both control *chikki* and nutra *chikki*, except in formulation. Screened peanuts, SPI and vitamins were mixed together. The jaggery was crushed and made into syrup by the addition of minimum amount of water and warmed till the jaggery dissolved and filtered through a nylon mesh (30 mesh size) to remove extraneous matter. Jaggery and peanuts were taken in equal ratios in control *chikki* and in nutra *chikki*, peanuts were replaced with SPI

and mineral mix. The jaggery syrup was heated with added mineral mix (CaCO_3 and ferrous fumarate) to the hard crack stage. All the ingredients were added to the hot syrup and mixed thoroughly for uniformity. The hot mass was transferred on to a tray, sheeted and cut into 2.5×5 cm with a cutter to obtain nutra *chikki*.

Physico-chemical characteristics of nutra *chikki* The various physico-chemical characteristics of nutra *chikki* were measured and compared with control *chikki*.

Texture measurement The breaking strength (N) or snap of nutra *chikki* was measured by following the triple beam snap method (also called 3 point break) using texture analyser (Model: LR – 5 K, Lloyds, England, UK). The sample (2.5×5 cm) of control and nutra *chikki* was taken and 3-point breaking test was performed using a load cell of 1 KN with 6 replicates with a cross head speed of 50 mm/min and 10 mm deflection. The Peak force at break, representing breaking strength was recorded and average values were reported.

Instrumental color measurement The surface color of nutra *chikki* was measured with 10-degree view angle and ΔE using CIELAB measuring system (Model, Lab scan, USA). The three parameters such as L^* , a^* , b^* and ΔE were measured. L^* represents lightness of the product, $+a^*$ redness, $-a^*$ represents green, $+b^*$ yellow, $-b^*$ represents blue and ΔE represents the total color difference of the samples.

Moisture estimation Moisture in *chikki* samples was determined by toluene distillation as per AOCS (1997b) procedure.

Oil was extracted from the products as per AOCS (2001) and peroxide value was also determined as per AOCS (1997a) procedure.

Protein estimation Crude protein was estimated by micro-kjeldahl method as per AOCS (1990) procedure. The protein conversion factor for dried peanuts is 5.46.

Mineral estimation Compositions of Ca and Fe in nutra *chikki* were determined by atomic absorption spectrophotometer (AAS) as per AOAC procedure (2000) and percent crude fibre was estimated by Fibre tech system as per AOCS procedure (1997a).

Protein digestibility-corrected amino acid score (PDCAAS) PDCAAS was calculated according to the method of Sarwar and McDonough (1990) using the essential amino acid composition of the test samples and amino acid patterns suggested by FAO/WHO/UNU for 10–12 year old children and adults (Devappa and Bhagya 2008).

Fatty acid estimation The oil extracted from *chikki* sample was used to determine fatty acid composition. The fats/oils are converted to fatty acid methyl esters (FAME) using 2 N methanolic/KOH as per AOCS procedure (1997a) and was analysed by GC (Varian GC-450, Netherlands) with FID and using SP 2380 fused silica capillary column (0.25 mm×30 m×0.2 µm film thickness) (Supelco, Bellefonte, PA, USA), programmed from 100 to 220 °C at 5 °C/min and maintaining at 220 °C for 5 min, injection temperature 220 °C, split ratio 1:20, detector temperature 250 °C and nitrogen flow 1 ml/min. The fatty acids were identified by using authentic standards and were reported as relative percentage.

Analysis of vitamin A Vitamin A in *chikki* was analysed by digesting the sample with ethanolic pyrogallol and ethanolic KOH for 18 h at 37 °C. After digestion, the vitamin A was extracted into solvent layer (hexane), separated and determined by high performance liquid chromatography (HPLC) (Shimadzu LC-10AS, Shimadzu Corp., Tokyo, Japan), C-18 (ODS) column 25 cm×4.6 mm id Supelco, Bellefonte, USA. Ultraviolet detector at a wavelength (λ) of 320 nm. The mobile phase consisted of 65% acetonitrile, 25% methanol and 10% chloroform with a flow rate of 1 ml/min (Chase et al. 2004).

Analysis of folic acid Extraction of folic acid from the sample (nutra and control *chikki*) was facilitated by partial enzymatic digestion (protease and papain at 45 °C for 1 h). An aliquot of the sample preparation was injected, separated and quantitated by HPLC model Shimadzu LC-10AS, (Shimadzu Corp., Tokyo, Japan), C-8 column (id) of 4.6 cm×150 mm Supelco, Bellefonte, USA. Detection is by absorption at 345 nm. The mobile phase used was a binary gradient with solution A - 0.16% sodium acetate and 0.3% sodium sulphate in water with pH 5.3 and solution B - 64% solution A and 36% acetonitrile with a flow rate of 1 ml/min at a run time of 25 min. Folic acid USP/NF grade was used as the reference (Jacoby and Franklin 1992).

Aflatoxin estimation Aflatoxins were extracted, purified and derivatized with trifluoroacetic acid (aflatoxins B1 and G1 to B2a and G2a respectively), separated by reverse-phase liquid chromatography, and detected by fluorescence as per AOAC (2000) procedure. This method can measure 0.1 ng of aflatoxins B1, B2, G1 and G2. Detection limit is ca 0.3 ng/g for each aflatoxin.

Sensory evaluation The sensory evaluation of freshly prepared nutra *chikki* was carried out with the help of a panel of 12 trained judges, following the method of Quantitative Descriptive Analysis (QDA) (Stone et al. 1974). The desirable characteristics of nutra and control *chikki* such as color, snap, hardness, crunchiness, sweetness, peanut flavour and the overall quality score were evaluated by drawing a vertical line on the scale for coded products.

Storage studies The storage studies of nutra *chikki* was carried out at accelerated (37±1 °C) and ambient (27±1 °C) temperatures by packing 100 g of the sample in 150 gauge polypropylene pouches for 105 days. The products were withdrawn every 15 days and the quality and stability of the product were evaluated by estimating the moisture, texture and peroxide value during storage at both temperatures.

Statistical analysis Student's t-test was applied to judge the significant difference among the means for sensory quality of nutra and control *chikki* (Cimino et al. 2005).

Results and discussion

Moisture of the *chikki* was very critical as it determines quality and stability of the product. Only marginal differences were observed in the moisture and fat content of both the control and nutra *chikki* samples. Similar results were reported for groundnut *chikki* (Chahal and Sehgal 1996). The protein content of nutra *chikki* was significantly

Table 1 Quality parameters of nutra and control *chikki* (per 100 g of product)

	Nutra <i>chikki</i>	Control <i>chikki</i>	RDA(10–15 years)
Moisture, %	2±1.23	2±1.66	–
Fat, %	20±0.31	21±0.42	22
Protein, %	18±0.77	12±0.65	55
Calcium, mg %	642±3.87	83±3.26	600
Iron, mg %	17±1.18	1.5±1.87	28
Crude fiber, %	1.4±0.55	1.6±0.32	–
Vitamin A, µg %	4000±100.54	–	600
Folic acid, µg %	2660±66.81	1840±65.47	70
Breaking strength, N	45.4±3.14	45.11±3.11	–
Aflatoxin	BDL	BDL	–

BDL = Below Detection Limits
All experiments were carried out in triplicate

increased due to the addition of SPI against the control *chikki* (Table 1). The minerals such as Ca and Fe in nutra *chikki* showed higher concentration due to the fortification of nutra *chikki* with CaCO_3 and ferrous fumarate, compared to those in the control *chikki*. The results showed that there is a decrease in the crude fibre content in nutra *chikki* compared to that of control *chikki* due to reduced peanut content. Aflatoxins B1, B2, G1 and G2 were found to be below detection limits (BDL) in both the control and nutra *chikki*.

The breaking strength of nutra *chikki* was similar to that of control *chikki* (Table 1). Similar results were observed during sensory analysis in hardness and crunchiness of both the *chikki* samples (Fig. 2).

Nutra *chikki* with the incorporation of nutraceuticals showed increased lightness in color compared to the dark brown color of control *chikki* which is due to the addition of SPI and minerals powder (Fig. 1).

The protein digestibility corrected amino acid score (PDCAAS), was determined by comparing the amino acid profile of nutra *chikki* against a standard amino acid profile, with 1 as the highest possible score. The main purpose of the PDCAAS is to rate the overall quality of a protein based on the amount of indispensable amino acids (IAAs) contained in nutra *chikki*. In nutra *chikki*, the main constituent, peanuts contain 3.50 g/16 gN lysine, which is a limiting amino acid in peanuts, is supplemented through SPI containing 6.60 gN lysine. The score is based on the amino acid that is in the shortest supply when compared to a reference (scoring) pattern. This scoring pattern is based on the IAA requirements of pre-school age children. The PDCAAS allows evaluation of food protein quality based on the needs of humans as it measures the quality of a protein based on the amino acid requirements (adjusted for digestibility) of a 2 to 5 year-old child (considered the most nutritionally-demanding age group). PDCAAS value of nutra *chikki* was 0.78 as against 0.73 of control *chikki* indicating improved protein quality and digestibility. Changes in few amino

Fig. 1 Colour measurement of control and nutra *chikki*. All experiments were carried out in triplicate

Fig. 2 Sensory evaluation of nutra and control *chikki*. All experiments were carried out in triplicate. Values with superscripts “a” and “b” in the figure differ significantly ($p \leq 0.05$) and no difference for other attributes

acids and mineral contents were reported (Khalil and Chughtai 1983).

No significant difference was observed in the fatty acid composition of control and nutra *chikki* as both contain peanuts as oil source, containing 22% saturated fatty acids and 45% monounsaturated and 29% polyunsaturated. Initially nutra *chikki* contains 4000 μg of vitamin A per

Fig. 3 Storage studies of nutra *chikki* at 27 °C and 37 °C. All experiments were carried out in triplicate, for breaking strength, $n=12$

100 g and on storage for 1 month at 27°C vitamin A content was reduced to 1800 µg. Vitamin A was absent in control *chikki*. This showed that nutra *chikki* contained vitamin A and meets part of RDA. The folic acid content in nutra *chikki* and control *chikki* was 2660 µg, 1840 µg respectively showing higher folic acid content in nutra *chikki* compared to control *chikki* per 100 g of the products.

Sensory analysis of nutra and control *chikki* showed that both the products were similar in all desirable quality attributes except for a difference in colour of nutra *chikki*, which is lighter in color compared to the dark brown color of control *chikki*. No significant differences were observed in the crunchiness, hardness and sweetness of both the *chikki* samples. But slight differences were observed in the snap, peanut flavour and overall quality of both the samples. Chahal and Sehgal (1996), have reported high overall quality scores for both groundnut *chikki* and sesame (til) *chikki*.

Similar difference in color was also observed in the instrumental color measurements. With respect to overall quality the mean scores did not differ between nutra *chikki* and control *chikki* (Fig. 2).

Nutra *chikki* had initial moisture content of 2–3% and there was no significant difference in moisture on storage at 27 and 37 °C up to 105 days. There was increase in PV at 27 °C whereas at 37 °C the increase in PV was significantly higher. No significant changes were observed in hardness of nutra *chikki* stored at 27 °C up to 105 days, whereas at 37 °C, a significant increase in hardness was observed after 45 days (Fig. 3).

Conclusion

The formulation and process for preparation of peanut *chikki* enriched with protein, mineral and vitamins were standardized. Physico-chemical and sensory characteristics of nutra *chikki* were comparable with those of control peanut *chikki*. Nutra *chikki* provides higher protein (18%), minerals (Ca 642 mg, Fe 17 mg) and vitamins (vitamin A 4000 µg, folic acid 2660 µg) compared to control *chikki* and thus was nutritionally superior and meets part of RDA requirement especially for children. Nutra *chikki* was found to be stable up to 105 days at 27 °C and up to 45 days at 37 °C.

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