Nutraceutical enriched Indian traditional *chikki*

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Abstract Chikki or peanut brittle, a traditional sweet snack was chosen as vehicle for enrichment with added natural nutraceuticals through herbs. The formulation and process for preparation of *chikki* with added herbs like ashwagandha (*Withania somenifera*), tulasi (*Ocimum sanctum* L.) and ajwain (*Trachyspermum ammi* S.) were standardized. The polyphenol content of *chikki* with added herbs ranged 0.29–0.46 g/100 g. Among the herbs, ajwain showed more potent antioxidant activity followed by tulasi, whereas ashwagandha and product prepared with it showed the least activity. Total carotenoid contents of *chikki* with added herbs ranged between 1.5 and 4.3 mg/100 g. Storage studies showed that *chikki* prepared with tulasi and ajwain were sensorily acceptable up to 90 days, while rancid notes were observed in control and *chikki* with added ashwagandha at the end of 30 days. Thus *chikki* with added herbs in addition to containing natural nutraceuticals like polyphenols and carotenoids had improved storage stability compared to control.

Keywords *Chikki* · Ashwagandha (*Withania somenifera*) · Tulasi (*Ocimum sanctum* L.) and ajwain (*Trachyspermum ammi* S.) · Antioxidant activity

Introduction

Nutraceutical or functional foods represent one of the fastest growing segments in food industry and have exploded in to the market. Every food category is seeking to jump in to this growing market. Prevention is as prevalent a reason for nutraceutical consumption as is treatment (Deck 2000). Examples

of dietary supplements are *Ginkgo Biloba* for memory loss, glucosamine and chondroitin for arthritis, vitamins, minerals, herbs and other botanicals, amino acids, enzymes, or other dietary substances etc. They are sold in many forms including tablets, capsules, liquids, powders, extracts and concentrates (Halsted 2003). Recent studies have clearly shown the potential of plant products to serve as antioxidants against various diseases induced by free radicals (Hou et al. 2003). Many studies have reported the biological activities of phenolics as a potent antioxidants and free radical scavengers (Kahkonen et al. 1999; Sugihara et al. 1999).

Flavonoids and polyphenols are currently the strongest mass market phytochemical ingredients; carotenoids, resveratrol, and anthocyanins are the next upcoming wave (Sloan 2011). Enhancing bioavailability by mixing phytochemicals is the latest new formulation direction. Consequently, an antioxidant supplement in the human diet is important to either prevent or reduce oxidative damage (Yang et al. 2002).

It was found that roasting significantly ($p \leq 0.05$) increased the antioxidant activity of the peanut kernel flour. It has been revealed that the optimum roasting time was essential for enhancing the antioxidant capacity and phenolics concentration in peanut kernel flour Win et al. (2011).

India has been recognized all over the world for its spices and medicinal plants. Both exhibit a wide range of physiological and pharmacological properties. Current biomedical efforts are focused on their scientific merits, to provide science-based evidence for their traditional uses and to develop either functional foods or nutraceuticals. Some medicinal herbs widely used in Indian ayurvedic preparations include ashwagandha, tulasi and ajwain.

Ashwagandha (*Withaniasomenifera*) is also known as Indian ginseng, is a plant in solanaceae or nightshade family. It is extensively used in traditional Indian herbal preparations as well as for modern nutraceutical and functional food supplements, (Dhanprakash et al. 2007). Ashwagandha is the

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herb that has been used as a powerful rejuvenator (*rasayanadravya*) in holy ayurvedic practice.

Tulasi (*Ocimum sanctum*) is also called Indian holy basil, is used in cooking and also for medicinal purposes. The beneficial effect of tulasi on blood glucose levels is due to its antioxidant properties. Tulasi also shows some promise for protection from radiation poisoning and cataracts. It has antioxidant properties and can repair cells damaged by exposure to radiation. Tulasi contains high concentration of eugenol (1-hydroxy-2-methoxy-4-allylbenzene). Tulasi has been used for thousands of years in ayurveda for its diverse healing properties and is mentioned in the *Charkasamhita*, an ancient ayurvedic text (Chopra et al. 1955).

Ajwain (*Trachyspermum ammi* L.) or Indian Bishop's weed, belonging to the family Apiaceae, is an important seed spice (Malhotra and Vijay 2004). Ajwain oil shows excellent antioxidant activity Gurdip et al. 1998; Mehta et al. 1994; Mehta and Zayas (1995). Saxena et al. (2004) established the quality standards of whole ajwain powder. Ajwain has been used in indigenous medicines for the treatment of diarrhea, dysentery, cholera, a tonic dyspepsia, flatulence, indigestion etc. The aqueous portion left after the separation of essential oil from ajwain is known as ovum-water (ajwain water) in India, used against flatulence and in gripe water preparation for children (Hajare et al. 2005) and described having anti hermitic, carminative, laxative, diuretic, flatulence preventive and dyspepsia preventive properties of ajwain (Sharangi and Datta 2005).

Chikki, called peanut brittle in the West, is a popular Indian sweet snack and is consumed by a large section of the population. *Chikki* is golden brown, hard crunchy product containing peanut pieces, with a characteristic peanut flavor. It fulfills the requirements of Indian army as a ready to eat food and as a concentrated source of energy (Vidyasagar et al. 1964). It is prepared in the shape of balls or slabs, various ingredients like puffed rice, puffed bengal gram, sesame, beaten rice and copra also go in the preparation of the product (Vidyasagar et al. 1964).

Chikki contains protein, fat, calcium, iron and folic acid (Pallavi et al. 2014); it has also been enriched with ω -3 fatty acids by incorporating flaxseeds (Chetana and Yella Reddy 2011). Gopika et al. (2014) studied the storage stability of *chikki* prepared with peanuts and sunflower kernels and shown that stored *chikki* had higher microbial load in the low density polyethylene (LDPE) when compared to that stored in laminated pouches. Also, *chikki* prepared with groundnut alone were preferred over those made in combination with sunflower and groundnut (1:1) or sunflower alone. However, all products were highly acceptable at the end of storage period of 2 months.

As this product is ready to eat and stable, it could be one of the good source to further enrich with nutraceuticals to meet the requirement of specific target groups. In the present study,

preparation and properties of *chikki* enriched with nutraceuticals in the form of ashwagandha (*Withaniasomenifera*), tulasi (*Ocimumsanctum* L.) and ajwain (*Trachyspermumammi* S.) are reported.

Materials and methods

Ashwagandha (*Withania somenifera*), tulasi (*Ocimum sanctum*) leaves, ajwain (*Trachyspermumammi*), peanuts, jaggery, were procured from the local market of Mysore.

Preparation of tulasi leaf powder The leaves of tulasi plants were cleaned with water and then oven dried at 65 °C for 2 h, the dried leaves were then crushed with a domestic mixer to make a powder.

Roasting of peanuts Peanuts were roasted at 120–140 °C, in a drum roaster for 25 min. The roasted peanuts were then split, de-husked, and germ removed. The peanuts were then crushed into small bits, which pass through the mesh size of 2.80 mm. The remaining peanut fines passing through the mesh size of 600 μ m, and 2.8 mm bits were mixed and used in the formulations.

Preparation of chikki The traditional method of *chikki* preparation was followed and the process was same for both control *chikki* and nutra *chikki*, except formulation. Peanuts bits (30 g), peanut fines (10 g) are mixed together, jaggery (60 g) along with 30 ml of water was heated to dissolve and the syrup was filtered to remove extraneous matter. This syrup was heated to 145 °C, peanuts bits (30 g) and fines (10 g) were added to the syrup, mixed thoroughly and poured on to a slab, sheeted to a defined thickness and cut into required size and packed in polyethylene pouches after cooling.

Preparation of nutra chikki Peanuts (30 g), peanut fines (5 g) and powder of each herb (3, 5, and 8 g) were mixed together separately *chikki* was prepared.

Instrumental color measurement The color of nutra *chikki* was measured with 10° view angle 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.

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 of control and nutra *chikki* were 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 of 10 readings were reported.

Moisture estimation In nutra *chikki* samples was determined by toluene distillation as per AOCS (1995) procedure. Oil content in the products was estimated as per AOAC (1995) and peroxide value of oil in *chikki* samples was determined.

Protein estimation Crude protein was estimated by micro-kjeldahl method as per AOCS (1995) procedure. The protein conversion factor for dried peanuts is 5.46.

Sensory evaluation The desirable characteristics of nutra *chikki* were evaluated sensorily using a 15 point linear rating scale ranging from 0 (lowest intensity on left) to 15 (highest intensity on right). 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) (Sidel and Stone 1993). The desirable characteristics of control and nutra *chikki* such as color, surface stickiness, hardness, snap, crunchiness, sweetness, peanut flavor, flavor (specific), rancidity, off taste and the overall quality score were evaluated by drawing a vertical line on the scale for coded products.

Storage studies The storage studies of control and nutra *chikki* were carried out at accelerated (37 ± 1 °C) and ambient (27 ± 1 °C) temperatures by packing 100 g of the each sample in polyethylene pouches. The products were withdrawn at every 15 days and the quality and stability of the product were evaluated by estimating the moisture, texture, color, peroxide value, fat content and sensory evaluation during storage at both temperatures.

Carotenoid estimation The carotenoid content in the sample is determined as per AOAC (2000) procedure,

Determination of total polyphenols The powdered nutra *chikki* and control *chikki* was extracted with 70 % aqueous methanol: water (3×10 ml) at 70 °C according to Singleton and Rossi 1965. The combined extracts were centrifuged at 6,000 rpm for 15 min, filtered and maintained at 30 ml each. Total polyphenols was estimated spectrophotometrically by Folin-Ciocalteu method with Gallic acid as the reference standard and expressed as gallic acid equivalent (GAE) in milligrams per 100 g of sample.

Measurement of reducing power The reducing power of total phenolics was determined according to the method of Yen and Chen (1995). The total phenolic extract (10–50 µg) of nutra *chikki* and standard gallic acid, (10–50 µg) were mixed

separately with an equal volume of 0.2 M phosphate buffer, pH 6.6 and 1 % potassium ferricyanide. The mixture was incubated at 50 °C for 20 min. An equal volume of 10 % trichloroacetic acid was added to the mixture and centrifuged at 3,000 rpm for 10 min. The upper layer of the solution was mixed with distilled water and 0.1 % FeCl₃ at a ratio of 1:1.2 (v/v) and the absorbance were measured using a spectrophotometer (Shimadzu UV-160 spectrophotometer, Tokyo, Japan) at 700 nm. An increase in the absorbance values compared to that of blank indicates higher reducing power.

Free radical scavenging activity The radical scavenging activity of total phenolic extracts of dried powders and nutra *chikki* prepared with them on DPPH radical was estimated according to the method of Lai et al. (2001). An aliquot of 500 µl of different phenolic fractions (1–5 mg, GAE) of nutra and control *chikki* and 1–5 mg of synthetic antioxidant (gallic acid) are taken. One milliliter of 0.10 mM DPPH in methanol was added to the sample to a final concentration of 75 µl. The mixture was shaken vigorously and left to stand for 20 min at room temperature in the dark. The absorbance of the resulting solution was measured spectrophotometrically at 517 nm. The capability to scavenge the DPPH radical was calculated using the following equation:

$$\text{Scavenging effect (\%)} = \frac{(\text{Absorbance of control} - \text{Absorbance of sample})}{\text{Absorbance of control}} \times 100$$

Principal component analysis (PCA) PCA is a widely used multivariate analytical statistical technique that can be applied to Qualitative Descriptive Analysis (QDA) data to reduce the set of dependent variables (i.e., attributes) to a smaller set of underlying variables (called factors) based on patterns of correlation among the original variables (Lawless and Heyman 1998). The data of various attributes stated above were arranged in ascending or in a descending order and put into the software SPSS 16 in data view mode. Then data were reduced by data analysis and the independent and dependent variables were selected and a two dimensional figure of the analysed sample was obtained.

Statistical analysis

Significant different between different treatments were established using LSD statistical method using Statistica V5.5 software (StatSoft, Tulsa OK, USA).

Results and discussion

Nutra *chikki* was prepared by incorporating herbs such as ashwagandha, ajwain and tulasi in the form of powders at

levels of 3, 5, and 8 % by weight of the product replacing of peanuts to supplement with nutraceuticals. The physico-chemical and sensory qualities of all the samples prepared were compared with those of control.

Physico-chemical characteristics of nutra Chikki Moisture, a critical parameter directly influencing the textural quality of *chikki*, ranged between 2.5 and 3.0 % in all the samples. The breaking strength of control *chikki* was 24 N, and that of nutra *chikki* prepared with addition of the three herbs differed depending on percentage of addition (Table 1). Nutra *chikki* prepared with herbs added at 3 % level was similar or closer to that of control, but at 5 % and 8 % levels, they showed higher breaking force and thus were harder.

Nutra *chikki* with added ashwagandha showed the least increase in breaking strength among various levels of incorporation and was similar to that of control *chikki*. Nutra *chikki* with added ajwain and tulasi at 5 and 8 % levels were harder with breaking strength of 31–35 N when compared with control, the former being harder than the later. The fat content of all the samples ranged between 20.6 and 21.7 %.

Instrumental colour measurement Addition of herbs imparted darker colour to nutra *chikki*, the intensity being highest in that with added tulasi as indicated by L* values (Table 1). Among the samples, *chikki* prepared with tulasi was the darkest at 8 % level, compared to others at the same level of incorporation. Tulasi imparted a greenish brown colour to *chikki*.

Sensory analyses Sensory analyses of all the products at 3, 5 and 8 % level of addition were carried out by comparing with those of control product (Table 1). Control *chikki* was light brown in colour, with added ashwagandha at 3 % level it was similar to control *chikki* in colour but at 5 and 8 % levels, the products were darker brown in colour. Addition of ajwain and tulasi also resulted in dark brown coloured products. Similar

results were observed in the instrumental colour measurements.

Snap and crunchiness which are critical quality attributes in *chikki* showed a score of 9.1–9.5 for control *chikki*. Nutra *chikki* prepared with Ashwagandha was found to be closer to that of control in textural attributes compared to the other herbs. Increasing the level of addition of the herbs showed a decrease in the snap and crunchiness.

Sweetness perception decreased significantly in *chikki* with addition of herbs at all the three levels compared to that of control. This could be attributed to the various taste and flavor of each specific herb, which were dominant and affected the sweetness perception.

Peanut flavor, which was found to be predominant in control *chikki* decreased with addition of herbs. Nutra *chikki* with ashwagandha added at 3 % level was close to that of control *chikki* with respect to flavour but all the other herbs had their own specific flavors, which were more dominating and suppressed the peanut flavor in *chikki*.

Overall quality showed a decreasing trend with increase in levels of addition of the herbs, addition at 3 % level being highly acceptability and 8 % level the least acceptable (Table 1). Therefore 5 % level of addition was chosen for further studies.

Storage studies of chikki prepared with added herbs The characteristics of nutra *chikki* with 3 herbs added at 5 % level on storage at 27 °C are shown in Table 1. The moisture content increased with increasing days of storage in all the samples including control and marginal differences were observed among different *chikki* samples.

A decrease in breaking strength was observed with an increase in days of storage in all the samples. *Chikki* lost its characteristic snap and crunchy texture on storage after 40–45 days of storage at 27 °C. The peroxide value ranged between 1.6 and 2.15 initially, increased with an increase in

Table 1 Characteristics of *chikki* prepared with herbs at different concentrations

Nutra <i>chikki</i>	Incorporation (%)	Moisture (%)	Breaking force (N)	Colour values (L*)	Overall quality score
Control	—	2.87±0.91 ^{bc}	24.28±1.22 ^c	52.31±1.08 ^h	13.62±1.54 ^e
Ashwagandha	3	2.82±1.03 ^{bc}	20.58±1.41 ^a	50.06±0.96 ^g	14.13±1.52 ^f
	5	2.92±0.94 ^{bc}	23.01±1.13 ^b	47.36±0.66 ^f	11.19±1.55 ^c
	8	3.11±1.32 ^d	25.62±1.84 ^d	43.57±1.07 ^d	9.02±1.21 ^a
Ajwain	3	2.68±1.06 ^b	23.82±1.25 ^b	46.84±1.11 ^e	11.27±1.29 ^c
	5	2.92±0.89 ^{bc}	32.90±1.65 ^g	46.79±1.24 ^e	10.33±1.05 ^b
	8	2.73±1.20 ^c	35.43±1.33 ^h	39.09±0.93 ^c	9.68±1.17 ^a
Tulasi	3	2.52±1.37 ^a	24.02±1.87 ^c	34.10±0.99 ^b	13.83±1.14 ^e
	5	2.65±1.41 ^b	28.92±2.01 ^e	34.42±1.28 ^b	12.01±1.11 ^d
	8	2.89±0.95 ^{bc}	31.62±2.41 ^f	33.09±1.41 ^a	9.82±1.23 ^a

Values with different superscripts in a column within the group differ significantly at $p \leq 0.05$

the storage period. At 90 days of storage, the peroxide value of the control *chikki* was significantly higher than those of nutra *chikki* with added herbs (Fig. 1). The moisture content of all the samples showed significant increase during storage at 37 °C up to 90 days. The breaking strength of nutra *chikki* samples decreased on storage. This could be due to increase in moisture, thus making the products soft at the end of 90 days. Peroxide values on storage showed a gradual increase on storage up to 90 days in all the *chikki* samples (Fig. 1). The PV of control and ashwagandha added *chikki* increased from 2.1 to 9.5 and 8.5 meqO₂/Kg respectively. Rancid notes were detected in both on the 90th day. In ajwain and tulasi added *chikki* the PV increased from 2.1 to 7.2 and 7.5 respectively indicating better storage stability.

Colour measurement of Chikki at 27 °C and 37 °C Addition of herbs resulted in darkening of the product and a gradual increase in intensity was observed on storage as shown by a decrease in L* values. The extent of decrease in L* is same in all the samples including control sample. *Chikki* prepared with ashwagandha showed only a slight decrease in L* and remained almost same at the end of 90 days of storage. Ashwagandha powder, which is creamish to light brown in colour imparted a light colour to the *chikki*, thus *chikki* with added ashwagandha

powder was light in colour and similar to that of control. *Chikki* with added ajwain was darker than control, as ajwain seeds are brown and hence increased the total colour in the *chikki*. Tulasi being dark green in colour, when added to *chikki* was the darkest among the three added herbs (Table 2).

The colour of *Chikki* stored at 37 °C were similar to those observed at 27 °C, but at the end of 90 days of storage, they were slightly darker compared to those observed at 27 °C (Table 2). *Chikki* with ajwain and tulasi did not show much difference in ΔE (total colour difference) during storage.

Sensory analysis of Chikki at 27 °C Sensory analysis of *chikki* prepared with added herbs at 5 % level showed that all the products were highly acceptable. Significant differences were observed in colour among the samples. Snap and crunchiness of *chikki* decreased during storage. At ambient conditions, control *chikki* was found to have good snap and crunchiness up to 60 days, whereas *chikki* with ashwagandha, ajwain and tulasi, were crunchy up to 30 days of storage after which crunchiness reduced gradually (Table 3).

Sweetness of *chikki* decreased with addition of the herbs, although the quantity added remains same for all the products. Similarly, peanut flavor, which was found to be dominant in the control sample, decreased on adding the herbs at 5 % level each had their own characteristic flavour. Rancid notes were only slight and could be detected initially at the end of 30 days in control *chikki* whereas it was after 60 days in *chikki* with added herbs. *Chikki* with added tulasi was found to have the highest overall quality followed by ajwain and then ashwagandha and were higher than that of control *chikki*.

Sensory analysis of Chikki at 37 °C Sensory qualities of *chikki* stored at 37 °C were found to be similar to those stored at 27 °C. The colour of *chikki* was significantly darker at 37 °C, snap and crunchiness was found to be lower at the end of 30 days of storage. Rancid notes were observed after 30 days and gradually increased up to 90 days storage, (Specific flavor of herbs decreased more rapidly at 37 °C). Rancid notes were lower in *chikki* with added ajwain and tulasi than that in ashwagandha and control *chikki*. At 90 days, control *chikki* and that with ashwagandha were unacceptable but those with ajwain and tulasi were moderately acceptable (Table 4).

Polyphenols and antioxidant activity of herbs and Chikki prepared with them The total polyphenols in ajwain seeds are higher than those in other herbal powders and least in ashwagandha powder and same trend was observed in *chikki* prepared with these herbs (Table 5). The results in the Table 6 showed that the IC 50 values of herbal powders were comparable with those of synthetic antioxidants. Similarly *chikki* with added herbs showed lower IC 50 values compared to control showing the potential of antioxidant activity of these herbs. The differential free radical scavenging ability of herbs

Fig. 1 Physico-chemical characteristics of nutra *chikki* prepared with 3 different herbs stored at 27 °C and 37 °C

Table 2 Instrumental colour values of Nutra *Chikki* prepared with herbs added and stored at 27 °C and 37 °C

Nutra <i>Chikki</i>	Days of storage	Instrumental colour values							
		L*		a*		b*		ΔE	
		27 °C	37 °C	27 °C	37 °C	27 °C	37 °C	27 °C	37 °C
Control	0	52.58±1.02	52.58±1.31	12.48±1.48	12.48±1.07	34.93±1.19	34.93±1.10	50.68±0.98	50.68±1.36
	30	50.15±1.03	50.26±1.24	12.76±1.23	12.84±1.30	37.64±1.63 ^a	38.22±1.25 ^b	53.41±1.12	53.13±1.11
	60	50.19±1.05 ^a	47.61±1.6 ^b	12.77±1.08 ^a	13.91±1.61 ^b	36.44±1.97 ^a	24.67±1.28 ^b	53.27±0.91	53.37±1.36
	90	44.11±1.15 ^a	46.02±1.22 ^b	13.34±1.29 ^a	14.21±1.14 ^b	29.43±1.05 ^a	36.65±1.13 ^b	56.92±1.02	56.41±0.89
Ashwagandha (5 %)	0	48.23±1.22	49.01±1.14	09.86±1.11 ^a	10.68±1.50 ^b	29.04±1.10 ^a	31.01±1.50 ^b	52.99±1.08	52.68±0.80
	30	47.55±1.32	47.56±1.28	12.34±1.67	12.31±1.56	33.38±1.54	33.38±1.46	54.21±1.10	54.21±1.09
	60	46.56±1.19	45.93±1.51	11.12±1.47	11.28±1.23	29.04±1.40	29.49±1.45	52.99±1.92 ^a	55.13±1.04 ^b
	90	44.12±1.54	44.65±1.31	14.53±1.24	14.45±1.22	28.74±1.11	29.28±1.73	56.11±1.08	56.37±1.64
Ajwain (5 %)	0	35.57±1.51	32.57±1.47	13.32±1.18	13.32±1.27	32.38±1.03	32.28±1.52	66.14±1.53	66.14±1.55
	30	33.03±1.03 ^b	31.99±1.58 ^a	12.79±1.78	16.24±1.82	23.99±1.15 ^a	25.42±1.56 ^b	65.09±1.20 ^a	66.31±10.8 ^b
	60	32.42±1.32 ^b	31.22±1.02 ^a	12.25±1.23	11.88±1.31	29.52±1.57 ^a	27.56±1.35 ^b	65.54±1.17 ^a	66.03±1.33 ^b
	90	31.63±1.51 ^b	31.92±1.46 ^a	14.98±1.71 ^a	16.28±1.64 ^b	24.89±1.67 ^a	25.42±1.61 ^b	66.34±1.24	66.31±1.17
Tulasi (5 %)	0	36.48±1.18	36.48±1.11	03.77±1.06	03.77±1.18	25.32±1.32	25.31±1.82	61.01±1.16	61.01±1.11
	30	35.24±1.14 ^b	34.94±1.84 ^a	03.78±1.77	03.25±1.72	18.95±1.67	21.35±1.12	62.25±1.31 ^a	64.24±0.94 ^b
	60	31.63±1.07 ^a	33.92±1.09 ^b	03.49±1.63 ^a	06.77±1.98 ^b	19.86±1.71 ^a	19.97±1.63 ^b	65.22±1.09 ^a	63.46±1.17 ^b
	990	30.22±1.12 ^a	32.22±1.16 ^b	03.15±1.34 ^a	09.21±1.47 ^b	18.56±1.28	22.45±1.72	64.33±1.65	65.13±1.65

Values with different superscripts in a column differ significantly ($p \leq 0.05$) between treatments

and also *chikki* prepared with added herbs showed lower IC₅₀ values compared to those of control showing free radical scavenging effect, i.e., more potent antioxidant activity of herbs. Among the herbs ajwain powder, showed the highest

antioxidant activity whereas, ashwagandha and product prepared with it showed the least activity. The anti-oxidant activity of these herbs was further confirmed by % inhibition of DPPH (Table 6). Ajwain powder showed higher inhibition

Table 3 Sensory evaluation of Nutra *chikki* prepared with herbs added at 5 % level stored at 27 °C

Nutra <i>Chikki</i>	Days of storage	Colour	Peanut flavour	Flavour (specific)	Snap	Crunchy	Sweet-ness	Rancidity	Overall quality score
Control	0	02.6±0.25 ^a	10.6±1.24 ^c	ND	9.5±1.23 ^e	9.7±1.02 ^e	10.9±1.25 ^e	ND	13.6±0.98 ^g
	30	03.3±0.88 ^b	10.1±1.31 ^c	ND	8.0±0.83 ^d	8.7±1.32 ^d	10.0±1.31 ^f	2.0±0.02 ^b	11.3±1.21 ^g
	60	04.5±0.71 ^c	7.0±1.27 ^d	ND	5.9±0.99 ^c	8.2±0.98 ^d	9.3±1.27 ^d	4.4±0.07 ^d	7.2±1.69 ^h
	90	04.5±0.32 ^c	6.5±1.32 ^c	ND	4.0±1.01 ^a	4.3±0.68 ^a	9.2±1.01 ^d	6.0±0.05 ^e	4.3±1.32 ^h
Ashwagandha (5 %)	0	04.6±0.24 ^c	6.1±1.20 ^c	4.5±1.22 ^a	9.7±0.92 ^e	8.6±1.01 ^d	9.3±1.34 ^d	ND	11.0±1.01 ⁱ
	30	05.5±0.18 ^d	6.2±1.01 ^c	5.5±1.28 ^b	8.0±0.64 ^d	8.3±1.05 ^d	9.3±1.18 ^d	ND	9.8±1.74 ^j
	60	06.6±0.17 ^e	4.8±1.12 ^a	5.6±1.32 ^b	5.3±1.21 ^c	5.3±1.12 ^b	8.6±1.29 ^{bc}	1.3±0.05 ^a	8.0±1.21 ^a
	90	06.5±0.87 ^e	4.0±1.21 ^a	6.1±1.41 ^{bc}	4.8±1.37 ^b	5.2±0.99 ^b	8.3±1.87 ^{bc}	2.5±0.17 ^c	6.5±1.33 ^b
Ajwain (5 %)	0	11.6±0.11 ^f	6.0±1.09 ^c	9.1±2.11 ^d	8.8±1.73 ^{de}	9.1±1.74 ^e	8.3±1.29 ^{bc}	ND	10.3±1.25 ^c
	30	12.0±0.72 ^g	5.3±1.14 ^{ab}	8.8±2.19 ^e	8.2±0.87 ^d	8.5±1.35 ^d	8.0±1.45 ^b	ND	9.6±1.69 ^c
	60	12.6±0.63 ^g	5.1±1.06 ^{ab}	8.1±2.04 ^e	5.6±0.62 ^c	6.1±1.21 ^c	7.1±1.17 ^{ab}	1.0±0.25 ^a	8.0±1.06 ^d
	90	13.0±0.35 ^g	4.5±1.16 ^a	7.4±1.90 ^c	4.3±1.02 ^a	4.5±0.67 ^a	6.0±1.21 ^a	2.0±0.39 ^b	7.0±1.01 ^d
Tulasi (5 %)	0	13.5±0.18 ^{gh}	5.6±1.08 ^{ab}	7.6±1.08 ^c	8.6±1.08 ^{de}	8.3±1.74 ^d	8.3±1.16 ^{bc}	ND	12.0±0.98 ^d
	30	13.2±0.87 ^{gh}	5.3±1.17 ^{ab}	7.6±0.99 ^c	8.0±1.28 ^d	8.0±1.10 ^d	8.0±1.44 ^b	ND	10.6±0.91 ^e
	60	13.8±0.14 ^{gh}	5.0±0.98 ^{ab}	7.0±1.95 ^c	6.0±1.62 ^c	6.6±1.62 ^c	7.8±1.92 ^b	1.0±1.12 ^a	9.0±1.23 ^f
	90	14.0±0.89 ⁱ	4.4±1.24 ^a	6.8±1.98 ^c	4.8±0.85 ^b	4.2±1.79 ^a	7.5±1.09 ^b	1.8±1.01 ^b	8.0±1.17 ^f

Values with different superscripts in a column differ significantly ($p \leq 0.05$)

ND Not Detected

Table 4 Sensory evaluation of Nutra *chikki* prepared with herbs added at 5 % stored at 37 °C

Nutra <i>Chikki</i>	Days of storage	Colour	Peanut flavour	Flavour (specific)	Snap	Crunchy	Sweet-ness	Rancidity	Overall quality
Control	0	2.6±0.69 ^a	10.6±0.35 ^f	ND ^a	9.5±0.31 ^f	9.1±1.07 ^g	10.9±1.12 ^f	ND	13.6±1.02 ^j
	30	4.3±1.07 ^b	10.4±0.78 ^f	ND ^a	6.5±0.91 ^c	6.3±1.20 ^d	10.5±1.07 ^f	3.0±0.31 ^c	9.6±0.94 ^f
	60	5.1±0.98 ^c	9.5±0.99 ^e	ND ^a	5.1±0.89 ^b	4.5±1.66 ^b	9.5±0.69 ^e	4.5±0.33 ^d	6.5±1.06 ^c
	90	5.5±1.21 ^c	7.5±0.71 ^d	ND ^a	4.2±0.27 ^a	3.2±1.43 ^a	7.5±1.16 ^d	5.6±0.15 ^e	3.6±1.12 ^a
Ashwagandha (5 %)	0	4.6±1.27 ^b	6.5±0.83 ^c	6.8±0.14 ^c	9.7±0.74 ^f	8.6±1.82 ^f	9.0±1.18 ^e	ND	11±1.28 ^h
	30	5.2±1.50 ^c	6.3±0.32 ^c	6.5±0.07 ^c	6.4±0.66 ^c	6.2±1.69 ^d	9.1±1.23 ^e	1.1±0.28 ^a	10±1.65 ^g
	60	6.2±1.63 ^d	5.5±0.61 ^c	5.5±0.12 ^b	5.6±0.49 ^b	5.4±1.54 ^c	9.2±0.86 ^e	2.5±0.33 ^c	7.6±1.28 ^d
	90	6.8±0.99 ^d	5.2±0.75 ^b	5.1±0.14 ^b	4.3±0.73 ^a	4.2±0.98 ^d	7.8±1.05 ^d	3.2±0.37 ^c	5.8±1.08 ^b
Ajwain (5 %)	0	11.6±1.06 ^e	6.1±0.64 ^b	9.2±0.03 ^f	8.8±0.64 ^e	9.1±1.32 ^g	8.3±1.51 ^d	ND	10.3±1.74 ^g
	30	12.2±1.92 ^f	4.5±0.89 ^a	9.3±0.16 ^f	7.6±0.28 ^d	6.9±1.10 ^d	8.1±0.42 ^d	ND	8.2±1.37 ^e
	60	12.8±1.01 ^f	4.3±0.97 ^a	8.5±0.32 ^c	7.3±0.14 ^d	5.0±1.27 ^c	6.8±1.13 ^c	1.1±0.06 ^a	7.2±1.61 ^b
	90	13.6±1.21 ^g	4.2±0.19 ^a	8.3±0.11 ^c	5.0±0.24 ^b	4.2±1.23 ^b	6.2±0.89 ^c	2.0±0.08 ^b	6.4±1.35 ^c
Tulasi (5 %)	0	13.0±1.51 ^g	5.6±1.01 ^c	7.6±0.17 ^d	8.6±0.26 ^e	8.3±1.87 ^f	8.3±0.70 ^d	ND	12.3±1.08 ⁱ
	30	13.5±1.63 ^g	5.2±0.26 ^b	7.3±0.07 ^d	8.4±1.01 ^e	7.2±1.06 ^c	7.2±1.06 ^d	ND	9.5±1.65 ^f
	60	14.2±1.32 ^h	5.1±0.49 ^b	7.1±0.13 ^d	8.2±1.03 ^e	5.2±1.01 ^c	5.2±0.33 ^b	1.6±0.86 ^b	7.5±1.78 ^d
	90	14.2±1.19 ^h	5.0±0.51 ^b	6.8±0.18 ^c	7.6±1.00 ^b	4.1±1.29 ^b	4.1±0.76 ^a	2.0±0.91 ^b	6.6±1.92 ^c

Values with different letters in a column differ significantly ($p \leq 0.05$)

ND Not Detected

compared to those of others. This is further confirmed by the reducing power ability of phenolics from ajwain powder compared to the others. The results revealed that the polyphenols from ajwain powder have a marked antioxidant activity followed by tulasi and ashwagandha. The same trend was followed in *chikki* prepared using these herbal powders

Chowdhury et al. (2008) studied the enzymatic activity of herbal yoghurt. They added tulasi, pudina and coriander leaves to yoghurt and found that the antioxidant activity of tulasi leaf was maximum containing the highest number of active biomolecules which enhanced the enzymatic activity of β -galactosidase in yoghurt. Singh et al. 2007 emphasized that extracts of ajwain possess excellent anti-microbial properties and strong antioxidant activity by DPPH and other radical scavenging assays.

Carotenes In addition to polyphenols, herbs contain carotenes, tulasi being the highest and ashwagandha the least.

Chikki samples also followed the same trend and they had higher carotenes compared to control (Table 5)

Results of the storage studies revealed that *chikki* prepared with tulasi and ajwain were sensorily acceptable up to 90 days of storage at ambient temperature conditions. Control *chikki* and that with added ashwagandha samples showed slight rancid notes by the end of 30 days. Thus *chikki* with added herbs in addition to containing natural nutraceuticals like polyphenols and carotenoids had better storage stability compared to control.

Principal component analysis (PCA) The principal component analysis (PCA) of *chikki* with different herbal powders indicated that PC 1 accounted for 46.9 % of the variation, while PC2 accounted for 22.6 % variation such that a total of 69.5 % variation (Fig. 2) can be explained by these two axes indicating the model constructed is a significant one in

Table 5 Total phenols and total Carotenoid content of dry herbal powder and Nutra *chikki* prepared with herbs added at 5 % level

Sample	Total Polyphenols		Total Carotenoids	
	Dry powder (g/100 g)	Nutra <i>Chikki</i> (g/100 g)	Herbal powder (mg/100 g)	<i>Chikki</i> sample (mg/100 g)
Control	—	0.29 ^a ±0.01	—	1.50 ^a ±0.01
Ashwagandha	0.43 ^b ±0.04	0.35 ^b ±0.02	0.42 ^a ±0.01	1.76 ^a ±0.02
Tulasi	2.43 ^a ±0.06	0.39 ^b ±0.02	6.54 ^c ±0.03	4.32 ^c ±0.04
Ajwain	2.52 ^a ±0.05	0.46 ^c ±0.02	3.71 ^b ±0.02	2.53 ^b ±0.03

Values with different superscripts in a column differ significantly ($p \leq 0.05$)

Table 6 Free radical scavenging effect (antioxidant assay) of dry herbal powder and Nutra *chikki* prepared with herbs at 5 % addition

Sample	Herbal powder IC ₅₀ (µg/ml)	% inhibition of DPPH at 5 µg	Nutra <i>Chikki</i> (5 %) IC ₅₀ (µg/ml)	% inhibition of DPPH
Control	–	–	8.32 ^a ±0.05	33.62 ^a ±0.01
Ashwagandha	5.36 ^c ±0.02	40.12 ^a ±0.04	7.18 ^c ±0.03	65.12 ^b ±0.02
Tulasi	3.98 ^a ±0.01	45.77 ^a ±0.03	6.02 ^b ±0.02	70.25 ^c ±0.04
Ajwain	3.57 ^a ±0.02	53.54 ^b ±0.04	6.18 ^b ±0.03	72.84 ^c ±0.04
BHT	3.82 ^a ±0.03	79.52 ^d ±0.06	3.87 ^a ±0.01	79.50 ^d ±0.05
TBHQ	4.14 ^b ±0.02	63.11 ^c ±0.05	4.14 ^a ±0.02	63.11 ^b ±0.02

Values with different superscripts in a column differ significantly ($p \leq 0.05$)

explaining the relationship among *chikki* samples with added herbal powders and quality parameters.

The control sample is closely related to overall acceptability (OA) and PV meaning that the high quality product is associated with control sample. However, the product with ajwain ashwagandha and tulasi are placed in opposite quadrants (Fig. 2). Ashwagandha and tulasi are similar and closely related. Addition of herbs to *chikki* showed that they were significantly different from that of control though acceptable sensorily. These results indicated that the quality characteristics of *chikki* studied with added herbs are different from control and could not be compared. However, they could be considered as different products.

The other independent variable i.e., concentration of added herbs is closely associated to total colour difference (TCD) meaning that an increase in concentration also increases TCD. The other group comprises of four quality parameters total polyphenols (TPP), carotenoids, radical scavenging activity (RSA) or antioxidant assay and breaking force (BF) are placed in the same quadrant and behaved as a single group. It means that an increase in any one of them automatically increases the

other. The OA however is inversely related to the group of physico chemical characteristics in addition to TCD and concentration, because of their placements in different quadrants. This shows that the traditional *chikki* and those with added herbs are different though they are acceptable.

Conclusion

Chikki, a popular sweet snack was chosen as vehicle to transfer natural nutraceuticals through herbs to consumers. The formulation and process for preparation of *Chikki* with added herbs like ashwagandha, tulasi and ajwain were standardized. Physico-chemical and sensory characteristics of *chikki* with added herbs are assessed in comparison with those of control. The polyphenol content of *chikki* with added herbs ranged 0.35–0.46 g/100 g as against 0.29 g/100 g in control. The free radical scavenging ability of herbs and also *chikki* prepared with them showed lower IC₅₀ values showing higher radical scavenging effect. Among these herbs, ajwain showed more

Fig. 2 Principal component analysis of nutra *chikki* with added herbs. OA – Overall quality; TCD- total colour difference; TPP- total polyphenols; CR –Carotenoids; RSA - Radical scavenging activity; BF- Breaking force (BF); Tul – tulasi, Ash – ashwagadha; Cont – Control; PV Peroxide Value

potent antioxidant activity followed by tulasi, whereas ashwagandha showed least activity. Similarly, the *chikki* prepared with ajwain and tulasi had higher antioxidant activity whereas control and *chikki* with added ashwagandha showed minimal activity. Total carotenoids content of *chikki* with added herbs ranged between 1.76 and 4.3 mg/100 g against 1.50 mg/100 g in control *chikki* highest being in *chikki* with added tulasi followed by ajwain and least in ashwagandha powder.

On storage the shelf life of *chikki* prepared with tulasi and ajwain were stable up to 90 days at ambient temperature conditions while rancid notes were observed in control and *chikki* with added ashwagandha at the end of 30 days. Thus *chikki* with added herbs in addition to containing natural nutraceuticals like polyphenols and carotenoids had improved storage stability compared to control.

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