Chemical composition, rheological, quality characteristics and storage stability of buns enriched with coriander and curry leaves

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Abstract Effect of addition of normal (NL) and dehydrated (DL) curry leaves (*Murraya koeniggi*) and coriander leaves (*Coriandrum sativum*) in the ratio of 1:1 to refined wheat flour (WF) or a blend of refined wheat flour-whole wheat flour (WF-WWF, 1:1) on the rheological, nutritional, storage and quality characteristics of the buns were studied. Water absorption increased on addition of increasing levels of DL from 0 to 7.5 % to WF-WWF when compared to WF. Dough weakening was greater when DL was added to WF-WWF as seen in decrease in dough stability and abscissa at rupture values. Addition of gluten and emulsifiers improved the quality characteristics of buns prepared using either 25 % NL or 5 % DL. Storage stability of buns with DL was better. The protein, dietary fiber, iron and carotenoids in buns prepared from WF-WWF were higher. The results indicate the utilization of leaves in dehydrated form in the preparation of nutritionally improved buns.

Keywords Farinograph · Buns · Protein · Dietary fiber · Carotenoids

Practical Applications Coriander and curry leaves are utilized in the preparation of bakery products. Dehydration is a process, wherein maximum moisture is removed which improves the keeping quality of the material. Utilization of dehydrated leaves would be helpful reducing the cumbersome faced while the normal leaves are used. The results prove that incorporation of dehydrated leaves in the buns improved the nutritional characteristics of buns without significant changes in the flavour and colour of buns. Buns prepared using dehydrated leaves had a better shelf life.

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Introduction

Micronutrient malnutrition is a cause of concern in developing countries. Nutritional deficiency caused blindness; iodine-deficiency disorders and iron deficiency anemia are some of the major problems of micronutrient deficiency seen especially in children. Micronutrient deficiencies are also expressed in terms of increased mortality, morbidity and disability rates (Narasinga Rao 1997). One of the measures to prevent malnutrition among the population is through food-based approaches, which concentrate on change or improvement in food habits by creating awareness among selected populations (FAO 1996, 1997). Green leafy vegetables are less expensive, easily available and good sources of micronutrients. The use of green leafy vegetables requires promotion among selected populations to improve micronutrient status (Gopalan 1997). Pasta prepared using amaranth and spinach leaves had similar nutritional value and high consumer acceptability (Borneo and Aguirre 2008). Green curry leaves are one of the most commonly used spices in India (Prakash 1990) and a rich source of carotene (21,000 mg), β -carotene (7110 mg), calcium (830 mg) and iron (0.93 mg) per 100 g of leaves on a fresh weight basis (Gopalan et al. 1996). Among the Indian spices of nutritional and medicinal importance, coriander leaves were found to be rich in total carotenoid content (Aruna and Baskaran 2010). The volatile oils of about 2.6 % are present in fresh curry leaves (Dutta 1958). Raju et al. (2007) reported that the coriander and curry leaves also contain lutein apart from β -carotene. The medicinal properties of green leafy vegetables include anti-diabetic, anti-histaminic, anti-carcinogenic and anti-bacterial activities (Kesari et al. 2005). The tender leaves have higher enzymatic antioxidant status of peroxidase than matured leaves (Mahajan and Patil 2004). The hot extracts carried out using ethanol: water (1:1) had lesser antioxidant activity than the extracts carried out at ambient conditions (Sasidharan and Nirmala 2011). Curry

leaves are generally used in very small quantities for seasoning. Because of a slightly hard texture, curry leaves are generally discarded from the dish while eating. Hence, the nutritional potential of curry leaves remains underutilized. It is better to promote curry leaves in an edible form where larger quantities can be incorporated in the diet. One way to ensure greater consumption of curry leaves is to use curry leaves in dried form. Drying curry leaves also ensures shelf stability and convenience for use when required. Curry leaves are extensively used as a flavouring ingredient in South Asian, South East Asian, Chinese and Mexican cuisine. Addition of (5 %) dried curry leaf powder into chapati did not affect the chapati quality (Shanthala and Jamuna 2005). Fortification of bread or bakery products other than milk has been a long practice in western countries (Bauern Feind and Arroyare 1986). Retention of vitamin A (70 %) is observed after baking traditional bread from fortified flour (Sommer and West 1996).

In view of the above aspects, studies were carried out on addition of dried coriander and curry leaves (1:1) on rheological characteristics of the dough. Aim of the present study was to study the effect of normal leaves or dried leaves (curry:coriander at 1:1) to either refined wheat flour (WF) or refined wheat flour-whole wheat flour blend (WF-WWF) in the spice bun formulation rich in bioactive compounds. Further, proximate composition of the leaves and buns were carried out to know the retention of the nutrients.

Materials and methods

Materials

Commercial refined wheat flour (WF-Double nandi maida, Mysore) and whole-wheat flour (WWF-Pillsbury atta, Sunil Agro Foods, Bangalore) were procured from local market. Fresh curry (*Murraya koeniggi*) and fresh coriander leaves (*Corinadrum sativum*) procured from local market (Mysore, India) were cleaned in running water to remove the dust, spread on a muslin cloth until surface moisture was removed (Normal leaves-NL) and dried in a hot air flow oven at 40 °C for 4 h. Dried leaves were powdered using domestic grinder (Dehydrated leaves - DL) and stored at 6 °C till further use. Commercially available sugar powder, table salt, vanaspathi (hydrogenated fat), skimmed milk powder (Gujrat Co-operative Milk Marketing Federation Ltd, Anand, India), fresh green chilli and cumin seeds were used in the studies. Dry gluten powder (Burn's Philip, Pune), emulsifiers like glycerol monostearate (GMS) and sodium stearyl lactylate (SSL) from Biocon India, Pvt Ltd, Bangalore and fungal amylase (Sigma chemicals, USA) were used as additives.

Chemical characteristics

Moisture content, total ash, crude protein and total fat were determined in wheat flour, whole wheat flour, fresh/normal (NL) and dehydrated (DL) curry and coriander leaves according to the standard methods (AACC 2000). Determination of total dietary fibre (TDF), soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) were carried out according to the standard methods of AOAC (2000). Buns with and without NL/DL were also analysed for moisture, ash, protein, fat content, SDF and IDF as per the standard methods. All analysis for the samples were carried out in triplicates and expressed as the average value. The colour of raw materials (WF, WWF, NL and DL) were measured in terms of colour difference (ΔE), lightness (L^*) and colour (+ a: red, - a: green, + b: yellow, - b: blue) using Hunter Lab colour measuring system (Labscan XE, USA).

Extraction of carotenoids

Carotenoids were extracted from NL/DL leaves and buns incorporated with NL/DL according to the procedure described by Lakshminarayana et al. (2005). Carotenoids were extracted using ice cold acetone (final volume 400 mL) until the samples became colourless. Crude extract (50 mL) was taken in a separating funnel; 100 mL of petroleum ether and 100 mL of aqueous sodium chloride (25 %, w/v) were added, after mixing well, the upper layer was separated. The extraction was repeated and dried over anhydrous sodium sulphate (20 g) and filtered using Whatman No.1 filter paper. The filtrate was evaporated to dryness and re-dissolved in a known volume of hexane and an aliquot (100 μ L) was used for HPLC analysis. Sample handling, was done at dim light and at 4 °C to avoid photo-isomerization and oxidation of carotenoids. The carotenoids were separated on a C-18 column (25 cm $\times$ 4.6 mm $\times$ 4.6 μ m) using acetonitrile/methanol/dichloromethane (60:20:20) containing 0.11 % ammonium acetate as mobile phase at a flow rate of 1 mL/min, monitored at 450 nm with UV-Vis detector (Shimadzu, Kyoyo, Japan). The peak identities were confirmed by their retention times of standard chromatograms and were quantified from their areas.

Rheological characteristics

Dough properties of WF (CON-1) and WF-WWF (1:1; CON-2) samples incorporated with 0, 2.5, 5 and 7.5 % of dehydrated and powdered curry leaves and coriander leaves mixed in 1:1 ratio were determined using farinograph (Model no. 810108004, Brabender, Duisburg, Germany) according to standard AACC methods (54–21, 2000). Extensible properties of blends were determined using Chopin alveograph

according to standard AACC methods (54–30A, 2000). The maximum over pressure (P), average abscissa at rupture (L), index of swelling (G), curve configuration ratio (P/L) and deformation energy of dough (W) were recorded. Pasting characteristics of blends was studied using micro-visco amylograph. (Model No. 803201, Brabender Measurements and Control Systems, Duisburg, Germany) by taking 15 g sample on 14 % moisture basis and 100 ml distilled water with initial equilibrium at 30 °C and heating at the rate of 7.5 °C / min to a maximum temperature of 95 °C, holding for 3 min and cooling to 50 °C at the rate of 7.5 °C / min. The stirrer speed was 250 / min and measuring range was 300 cmg.

Preparation of buns

Buns were prepared using straight dough method from WF (CON-1) and WF-WWF (CON-2) samples. Dough was prepared by mixing flour (100 g), table salt (2 g), sugar (10 g), hydrogenated fat (10 g), skimmed milk powder - SMP (3 g) and water for 4 min in a planetary mixer and fermented for 1 h. At the remixing stage varying levels of either the chopped NL (0, 10, 20 and 30 %) or the powdered DL (0, 2.5, 5 and 7.5 %), chopped green chilli (2.5 %) and cumin seeds (1 %) were added and mixed for 2 min. Dough pieces (65 g) were rounded, proofed for 1 h and baked at 200 °C for 15 min. Buns were cooled and assessed for their weights and volume by rapeseed displacement method (Malloock and Cook 1930). Objective measurement of texture (crumb firmness) in triplicates was carried out in a texture analyser (TAHDI, Stable Micro Systems, Godalming, UK) by the standard AACC method (74–09). Six panelists carried out the sensory evaluation of buns for crust and crumb characteristics by assigning different scores for various parameters. The data was subjected to statistical analysis by Duncan's multiple range test (Steel and Torrie 1980). To improve the quality characteristics of buns, gluten (2 %), fungal alpha amylase (1 mg%), glycerol mono stearate (0.25 %) and sodium stearoyl lactylate (0.25 %) were added as additives.

Storage studies

Formulation of buns from WF (CON-1), WF-WWF (1:1, CON-2) and both enriched with either 25 % of NL or 5 % DL, the optimum levels of coriander and curry leaves (1:1) were used for carrying out the storage studies. Buns prepared were cooled to room temperature and packed in polypropylene pouches (75 micron). Calcium propionate (0.5 %) and glacial acetic acid (0.3 %) were added as preservatives. The control and leaf enriched bun samples were stored at ambient conditions and evaluated for moisture and crumb

firmness every alternate day till the development of mould growth (7 days). All analysis for the samples were carried out in triplicates and expressed as the average value.

Results and discussion

Quality characteristics of raw materials

The moisture content of curry leaves and coriander leaves on drying reduced from 69.9 % to 6.4 % and 85.7 % to 8.03 % respectively. The ash content was in the range from 9.9 to 13 % and the protein was in the range between 16.9–24.4 % on dry basis. The total dietary fiber in curry leaves was four times higher than coriander leaves (Table 1).

Rheological characteristics

Farinograph characteristics of WF-DL and WF-WWF-DL blends are presented in Fig. 1. Addition of DL to WF increased the water absorption from 61.1 to 62.8 %, dough development time increased from 1.8 to 2.4 min, mixing tolerance index increased from 26 to 63 BU and the farinograph quality number decreased from 75 to 71 indicating that the strength of the dough decreased. When the DL was added to WWF-WF, the water absorption increased from 63.2 to 66.7 %. Dough development time increased from 2.4 to 3.8 min and mixing tolerance increased from 59 to 110 BU. These data indicate that the addition of DL to WF-WWF decreased the strength of the dough to a greater extent. Similar results were obtained when dried moringa leaves were added to WF at different levels (Dachana et al. 2010). Chen et al. (1988) reported that interaction of gluten with added fiber affected the mixing properties of the dough.

Pasting characteristics (Fig. 1) of WF blended with varying levels of DL showed that there was marginal increase in gelatinization temperature from 65.6 to 67.4 °C. The peak viscosity, which indicate the ability of the starch to swell before breakdown decreased from 766 to 602 BU, hot paste viscosity decreased from 596 to 375 BU and cold paste viscosity decreased from 1047 to 836 BU. Addition of increasing levels of DL to WF-WWF decreased the peak viscosity, hot paste viscosity and cold paste viscosity from 655 to 588, 588 to 363 and 888 to 773 respectively (Fig. 1). Decrease in these values indicates that by increase in DL, the available starch content for gelatinization decreased. Similar results have been obtained when varying levels of apple pomace was blended with WF (Sudha et al. 2007).

Alveograph characteristics of these blends indicated the weakening effect on addition of these dehydrated leaves. The maximum over pressure values (P) increased marginally

Table 1 Chemical characteristics of raw materials

Sample	Moisture (%)	Ash** (%)	Protein** (%)	Fat** (%)	Dietary fiber** (%)	Colour			ΔE
						L*	a*	b*	
Refined wheat flour (WF)	10.9±0.01 ^c	0.49±0.01 ^d	9.9±0.11 ^d	0.48±0.24 ^d	5.5±0.27 ^b	90.8±0.21 ^a	0.1±0.32	9.4±0.41 ^d	8.4±0.11 ^d
Whole wheat flour (WWF)	8.2±0.11 ^d	1.50±0.02 ^c	12.6±0.23 ^c	1.9±0.42 ^a	12.1±1.35 ^c	83.9±0.33 ^b	1.23±0.41	14.4±0.23 ^a	16.0±0.25 ^c
Curry leaves (NL)	69.4±0.05 ^b	9.9±0.04 ^b	17.9±0.10 ^b	1.0±0.26 ^b	18.5±0.46 ^b	31.26±0.1 ^c	-7.27±0.12	11±0.34 ^b	60.64±0.23 ^a
Curry leaves (DL)	6.4±0.06 ^e	10.6±0.03 ^b	16.9±0.41 ^b	0.92±0.31 ^b	55.9±0.71 ^a	29.58±0.21 ^d	-6.22±0.13	10.46±0.33 ^{bc}	62.1±0.32 ^a
Coriander leaves (NL)	85.7±0.04 ^a	13.0±0.04 ^a	24.4±0.32 ^a	0.8±0.24 ^{bc}	5.2±0.91 ^d	36.45±0.41 ^c	-9.62±0.26	14.19±0.14 ^a	56.65±0.43 ^b
Coriander leaves (DL)	8.0±0.08 ^d	12.2±0.02 ^a	21.5±0.26 ^a	0.9±0.13 ^b	13.8±1.1 ^c	29.7±0.42 ^d	-4.98±0.24	10.34±0.10 ^{bc}	61.88±0.17 ^a

** On dry weight basis; Values are means ± standard deviation ($n=3$); WF Refined wheat flour; WWF Whole wheat flour; NL Normal leaves; DL Dehydrated leaves

on addition of DL to WF whereas with WF-WWF, the same decreased to a greater extent. Increase in maximum overpressure values as a result of incorporation of DL was however not corroborated in increase in values of abscissa at rupture (L). Incorporation of increasing levels of DL had adverse effect on the value of abscissa at rupture. Decrease in values of abscissa at rupture in dough also caused reduction in energy, a measure of alveogram area. Increasing levels of DL gradually reduced the energy value of dough from 154×10^{-4} to 60×10^{-4} J (Fig. 1).

Effect of normal coriander and curry leaves (NL) on the quality characteristics of buns

Buns were prepared using WF (CON-1) and WF-WWF (CON-2) and incorporating either NL (10, 20 and 30 %) or DL (2.5, 5 and 7.5 %). The data is presented in Table 2. Addition of increasing levels of NL from 0 to 30 % reduced the volume of buns from 250 to 225 cm³, thereby reducing the specific volume from 4.28 to 3.79 cm³/g. The crumb firmness as measured by food texturometer decreased from 453 to 387 g indicating that the addition of NL made the buns softer. The sensory scores for the crust colour, crumb colour, grain and overall quality were not affected at 10 % level, however at 20 and 30 % levels of NL incorporation, the crumb colour was more greenish and the grain was slightly compact and fine. The buns were softer as indicated by the lower firmness value. The volume of CON-2 sample was 175 cm³ and upon addition of NL from 0 to 30 %, the volume of the buns gradually decreased to 150 cm³ and there by the specific volume also decreased from 3.21 to 3.89 cm³/g. The firmness value which was 993 g for CON-2, reduced to 718 g with increase in the NL content. As a 1:1 WF-WWF blend was taken as CON-2 sample, the colour of the crumb was dull white and was significantly different from the crumb color of the CON-1. On addition of NL, the crust and crumb colour scores reduced. The grain was close and compact as the expansion was restricted due to the presence of bran in WWF. The crust and crumb colour values and the grain scores reduced as the level of leaves increased. These results indicated that addition of 20 % of NL would be suitable for preparing acceptable quality buns.

Effect of dehydrated coriander and curry leaves (DL) on the quality characteristics of buns

The results presented in Table 2 show that volume of the buns prepared with increasing levels of DL from WF decreased from 250 to 210 cc, thereby reducing the specific volume from 4.28 to 3.72. The extent of decrease was found to be greater when compared to the decrease observed when NL was incorporated. This may be due to the lower moisture content of DL which might have absorbed moisture from the

Fig. 1 Effect of dehydrated curry-coriander (1:1) leaves on the rheological characteristics of wheat flour / wheat flour-whole wheat flour blends. **a** Farinograph characteristics; **b** Alveograph characteristics; **b** Amylograph characteristics; *FWA* farinograph water absorption, *MTI* mixing tolerance index; *DDT* dough development time; *DS* dough stability; *P* maximum pressure; *L* extensibility; *W* energy; a-0 % blend; b-2.5 % blend; c-5 % blend; d-7.5 % blend CON 1 – Refined wheat flour (100 %); CON 2 – Refined wheat flour: Whole wheat flour (1:1)

Table 2 Effect of normal / dehydrated coriander and curry leaves (1:1) on the quality characteristics of buns

Coriander + curry leaves	Volume (cc)	Specific volume (cc/g)	Crust Colour (9)	Crumb colour (9)	Grain (9)	Texture		Overall quality (9)
						O (g force)	S (9)	
Normal leaves (NL)								
0 – CON 1	250±5.2	4.28±0.23	8.0a	8.0a	8.0a	453±2.0	7.5b	8.0a
10	245±3.2	4.20±0.31	8.0a	7.5ab	8.0a	444±5.1	7.5b	8.0a
20	233±4.6	3.93±0.42	7.0b	7.0b	7.5ab	400±3.8	8.0a	7.5ab
30	225±3.6	3.80±0.40	6.5c	6.5bc	7.0b	387±3.9	8.0a	6.5bc
0 - CON 2	175±3.9	3.21±0.21	8.0a	7.5ab	7.5ab	993±9.8	7.0c	7.5ab
10	165±4.6	3.15±0.15	7.5ab	7.0b	7.0b	875±8.9	7.0c	7.5ab
20	160±2.5	3.09±0.19	6.5c	6.5bc	7.0b	790±7.3	7.5b	7.0b
30	150±1.9	2.89±0.11	6.0d	6.0c	6.5c	718±4.6	7.5b	6.0c
Dehydrated leaves (DL)								
0 – CON 1	250±5.6	4.28±0.18	8.0a	8.0a	8.0a	453±3.6	7.5b	8.0a
2.5	230±4.9	4.18±0.21	7.5ab	7.5ab	8.0a	460±5.3	7.5b	7.0b
5.0	225±4.8	3.95±0.32	7.0b	6.5bc	7.0b	479±5.9	6.5d	6.5bc
7.5	210±3.7	3.72±0.42	6.0 cd	6.0c	6.5c	500±4.6	6.0e	6.0c
0 – CON 2	175±4.8	3.21±0.40	8.0a	7.5ab	8.0a	993±9.4	7.0c	7.5ab
2.5	155±3.2	2.88±0.38	7.0b	7.0b	7.0c	1095±10.2	7.0c	7.0b
5.0	145±2.6	2.64±0.34	6.0d	6.0c	6.5c	1215±9.9	6.0e	6.0c
7.5	140±3.1	2.49±0.31	6.0d	5.5d	6.0d	1301±10.8	5.5f	5.0d
SEM (±)	–	–	0.04	0.09	0.18	–	0.16	0.18

Values in the parenthesis indicate maximum score; Values are means ± standard deviation ($n=4$); Values for a particular column followed by different letters differ significantly ($p<0.05$); SEM Standard error of mean at 90° of freedom; CON 1 – Refined wheat flour (100 %); CON 2 – Refined wheat flour: Whole wheat flour (1:1); O Objective; S Subjective

dough and thereby restricted the expansion of the dough during baking. This is also reflected in the higher firmness values (460–500 g) as compared to the firmness of the buns prepared using NL (444–387 g). The crust and crumb colour scores were lower than the scores when normal leaves were incorporated. Since the DL were powdered and added, there was uniform distribution of green colour unlike the colour of the buns prepared using NL, where pieces of NL were visible. The sensory scores for grain and texture were lower than those of buns when prepared with NL. Similarly the buns prepared from CON-2 incorporated with DL reduced the volume of the buns from 175 to 140 cc, thereby reducing the specific volume of the buns from 3.21 to 2.49 cm³/g. The firmness values which were 453 g increased to 1301 g with the addition of increasing levels of DL to CON-2. The overall quality scores were lower than scores for buns prepared using CON-1 incorporated with DL and also when prepared with NL (Table 2). Acceptable quality buns can be prepared when DL is incorporated at 5 % to either WF or WF-WWF.

Effect of additives on the quality characteristics of buns

To improve the quality characteristics of buns prepared using CON-1 and CON-2, incorporated with suitable levels of NL (25 %) / DL (5 %), additives namely GMS (0.25 %), SSL (0.25 %), gluten (2 %) and α -amylase (1 mg) were used (Table 3). Addition of additives to CON-1 and CON-2 increased the volume and specific volume, whereas firmness values reduced. Addition of additives increased the volume

and specific volume of the buns (CON-1+25 % NL) from 220 to 245 cc and 3.85 to 4.15 respectively. Similarly addition of 5 % DL to CON 1 also increased the volume and specific volume from 225 to 240 cc and 4.09 to 4.29 respectively. Addition of additives also improved the texture of the buns as seen in the reduction in the firmness value. The sensory scores of the buns with additives also increased. The overall quality scores improved and the buns were highly acceptable. Similarly when 25 % NL or 5 % DL were incorporated to CON 2 and additives were used, the volume and specific volume values increased. The sensory scores for crumb colour, grain, texture and overall quality also increased. Additives are used to facilitate processing, to compensate for variation in raw materials and to assure quality product. Emulsifiers used might have bound to the protein hydrophobic surface resulting in a stronger protein network, thereby increasing the loaf volume and better texture (Kamal and Ponte 1993). It could be concluded that addition of GMS, SSL, gluten and α -amylase in combination helped in improving the quality characteristics of CON-1 and CON-2 buns and buns prepared with either 25 % NL / 5 % DL.

Storage studies of buns

Control buns (CON-1 and CON-2) and buns enriched with either 25 % of NL or 5 % of DL (with additives) were prepared and packed in poly propylene bags. Buns were stored at ambient conditions to study the quality characteristics of buns during storage. Bun samples were withdrawn

Table 3 Effect additives on the quality characteristics of buns enriched with normal/dehydrated coriander and curry leaves (1:1)

Sample	Volume (cc)	Specific volume (cc/g)	Crust Colour (9)	Crumb colour (9)	Grain (9)	Texture		Overall quality (9)
						O (g force)	S (9)	
CON 1	250±5.2	4.28±0.34	8.0a	8.0ab	8.0ab	453±3.6	7.5b	7.5b
CON 1 + Add	275±4.1	4.71±0.43	8.0a	8.5a	8.5a	320±2.9	8.5a	8.5a
25 % NL	220±4.3	3.85±0.27	7.0b	7.0bc	7.0c	420±4.2	7.5b	7.5b
25 % NL + Add	245±3.6	4.15±0.29	7.5ab	7.0bc	7.5b	400±4.9	8.0ab	8.0a
5 % DL	225±5.1	4.09±0.35	7.0b	6.5c	7.0c	479±2.8	6.5 cd	6.5 cd
5 % DL + Add	240±6.1	4.29±0.42	7.0b	6.5c	7.5b	450±6.0	8.0ab	7.5b
CON 2	175±4.3	3.21±0.36	8.0a	7.5b	7.5b	993±7.8	7.0c	7.5b
CON 2 + Add	190±3.9	3.42±0.31	8.0a	7.5b	8.0a	824±8.2	8.0ab	8.0ab
25 % NL	160±2.8	2.98±0.41	6.5bc	6.5c	7.0c	725±5.6	7.5b	7.0c
25 % NL + Add	175±3.4	3.15±0.27	7.0b	7.0bc	7.5b	670±7.6	8.0ab	7.5b
5 % DL	145±3.5	2.64±0.19	6.0c	6.0d	6.5 cd	1215±10.2	6.0d	6.0d
5 % DL + Add	165±3.6	3.09±0.14	6.0c	6.5c	7.0c	990±8.9	7.0c	7.0c
SEM (±)	—	—	0.11	0.16	0.15	—	0.19	0.12

Values in the parenthesis indicate maximum score; Values for a particular column followed by different letters differ significantly ($p<0.05$); SEM - Standard error of mean at 60 degrees of freedom; Values are means $\pm$ standard deviation ($n=4$); CON 1 – Refined wheat flour (100 %);

CON 2 – Refined wheat flour; Whole wheat flour (1:1); NL Normal leaves; DL Dehydrated leaves; Add Additives; O Objective; S Subjective

Fig. 2 Changes in the moisture content and crumb firmness of buns prepared from normal / dehydrated curry-coriander leaves (1:1) during storage at ambient conditions. Values are means $\pm$ standard deviation ($n=3$), MC Moisture content, CON 1 – Refined wheat flour (100 %), CON 2 – Refined wheat flour: Whole wheat flour (1:1), NL Normal leaves; DL Dehydrated leaves; 1, 3, 5 and 7 indicate the days on which buns were evaluated

every alternate day and analysed for moisture content, crumb firmness and mould growth. It is known that during storage the most evident changes are related to loss of moisture content and crumb hardening. The moisture content decreased and firmness values increased gradually for all the buns on storage (Fig. 2). It has been well explained that bread staling is a very complex process that cannot be explained by a single effect, amylopectin retrogradation, reorganisation of polymers within the amorphous region, loss of moisture content, distribution of water content between the amorphous and crystalline zone, and the crumb macroscopic structure must participate in the staling process (Davidou et al. 1996; Martin and Hosney 1991; Martin et

al. 1991; Rojas et al. 2001). Control buns were free of mould growth till 6 days of storage. Mould was observed in buns prepared using NL on 5th day, whereas mould appeared in buns with DL on 11th day. These results indicate that buns have longer shelf life when prepared using dehydrated leaves.

Nutritional characteristics of buns

Nutritional characteristics of buns are represented in Table 4. Control buns (CON-1 and CON-2) had ash and fat content in the range of 1.5–1.8 % and 9.4–9.6 % respectively. Whereas the buns enriched with either NL or DL had slightly higher ash content in the range of 2.20–2.67 %, which is due to the addition of mineral rich coriander and curry leaves. The protein content also increased upon addition of either 25 % NL or 5 % DL. The protein content of buns prepared from CON-2 was comparatively higher than CON-1 due to the presence of WWF which are higher in protein than WF. Also it is observed that addition of 5 % DL to either CON 1 or CON 2 has increased the protein content to a greater extent. The dietary fiber content increased upon addition of either NL or DL and was further more when buns were prepared from WF-WWF. The iron content of the CON-1 and CON-2 was 0.62 and 0.80 mg and on addition of 25 % NL or 5 % DL, iron content increased significantly (1.49–2.68 mg). Thus the buns from WF-WWF incorporated with either NL or DL were found to be more nutritious than prepared from WF only. Dachana et al (2010) supplemented WF with dried moringa leaves at 10 % level in cookie preparation and found significant increase in protein content, dietary fiber and iron content. Borneo and Aguirre (2008) showed that pasta prepared with either amaranth or spinach leaves had similar chemical composition, i.e. high content of protein and iron being contributed by the amaranth / spinach leaves.

Normal and dehydrated coriander and curry leaves along with buns incorporated with either of normal or dehydrated coriander and curry leaves were evaluated for neoxanthin (RT-3.6), lutein (RT-4.9) and β -carotene (RT-23.1). The

Table 4 Nutritional characteristics of normal/dehydrated coriander and curry leaves (1:1) enriched buns

Sample	Moisture (%)	Ash* (%)	Protein* (%)	Fat* (%)	Dietary fiber* (%)	Iron (mg%)
CON 1	12.3 $\pm$ 0.04	1.9 $\pm$ 0.01	6.7 $\pm$ 0.41	9.5 $\pm$ 0.21	3.2 $\pm$ 0.11	0.62 $\pm$ 0.09
CON 1 + 25 % NL	13.2 $\pm$ 0.08	2.4 $\pm$ 0.02	8.0 $\pm$ 0.32	9.4 $\pm$ 0.42	10.8 $\pm$ 0.60	1.49 $\pm$ 0.08
CON 1 + 5 % DL	10.1 $\pm$ 0.06	2.1 $\pm$ 0.04	9.2 $\pm$ 0.50	9.3 $\pm$ 0.34	9.8 $\pm$ 0.73	1.61 $\pm$ 0.03
CON 2	10.5 $\pm$ 0.05	1.5 $\pm$ 0.04	7.8 $\pm$ 0.61	9.6 $\pm$ 0.63	5.8 $\pm$ 0.62	0.80 $\pm$ 0.04
CON 2 + 25 % NL	13.0 $\pm$ 0.03	2.7 $\pm$ 0.01	9.3 $\pm$ 0.43	9.5 $\pm$ 0.71	14.4 $\pm$ 0.61	2.16 $\pm$ 0.07
CON 2 + 5 % DL	10.2 $\pm$ 0.04	2.2 $\pm$ 0.07	10.1 $\pm$ 0.60	9.3 $\pm$ 0.62	11.3 $\pm$ 0.37	2.68 $\pm$ 0.06

Values are means $\pm$ standard deviation ($n=3$); CON 1 – Refined wheat flour (100 %); CON 2 – Refined wheat flour: Whole wheat flour (1:1); NL Normal leaves; DL Dehydrated leaves

Table 5 Carotenoid composition* of normal and dehydrated coriander and curry leaves enriched buns

SAMPLE	Neoxanthin (mg/100 g)	Lutein (mg/100 g)	Beta carotene (mg/100 g)
Coriander leaves	3.8±0.64	11.1±0.75	74.8±0.91
Dehydrated coriander leaves	5.3±0.81	7.6±0.33	59.4±0.72
Curry leaves	5.7±0.42	22.4±0.82	64.9±0.37
Dehydrated curry leaves	6.7±0.63	18.2±0.41	51.4±0.62
Buns			
CON 1	0.01±0.01	0.48±0.06	–
CON 2	0.04±0.03	0.92±0.03	–
CON 1 + 25 % NL	0.32±0.04	2.9±0.11	2.2±0.40
CON 2+ 25 % NL	1.6±0.01	4.1±0.30	3.2±0.31
CON 1 + 5 % DL	0.95±0.04	3.8±0.21	3.6±0.09
CON 2+ 5 % DL	2.0±0.03	4.0±0.33	3.7±0.08

Values are means ± standard deviation ($n=3$), *mg/100 g on dry weight basis; CON 1 – Refined wheat flour (100 %), CON 2 – Refined wheat flour: Whole wheat flour (1:1); NL Normal leaves; DL Dehydrated leaves

concentration of these carotenoids in leaves (NL / DL) and in buns with and without NL/DL is presented in Table 5. The neoxanthin content in coriander and curry leaves were in the range of 3.8–5.7 mg/100 g dry wt), however curry leaves had higher levels of lutein (22.35 mg/100 g dry wt) and coriander leaves had higher levels of β -carotene (74.88 mg/100 g dry wt). These data are different from the data as reported by either Raju et al. (2007) or Tee and Lim (1991). The variation in results may be due to variation in species, climatic or geographic conditions, degree of maturation at harvest, cultivation and post harvesting practices (Chen and Chen 1992). These results indicate that these leaves can be a source of lutein, a natural antioxidant.

The leaves on dehydration showed that the carotenoid composition was affected. The neoxanthin content increased, whereas lutein and β -carotene content decreased. This could be attributed to degradation of carotenoids by residual peroxidase enzyme in the samples. The level of neoxanthin which is the most common allene in the leafy vegetables and also associated with lutein was found to be higher in both the leaf samples after dehydration. This demonstrates the transfer of the end group of one of the lutein which may perhaps be responsible for the formation of allenic end group. The differences between lutein and neoxanthin in samples may be attributed to these biosynthetic transformations.

In CON-1 and CON-2 buns samples, traces of neoxanthin and lutein were obtained, whereas β -carotene was not detected. After addition of 25 % NL to the buns, the CON- 2 sample had higher amounts of lutein, neoxanthin and β -carotene content than CON-1 sample. However addition of 5 % DL to CON-1 or CON-2 increased the lutein, neoxanthin and β -carotene contents. This indicates that larger amounts of leaves can be incorporated in dehydrated form, which would thereby supplement these bioactive components to a greater extent. Thus the significant amounts of carotenoids were observed in DL supplemented buns when compared to NL supplementation. Addition of DL can be

considered for supplementation of lutein and β -carotene, the bioactive molecules from a natural source through a convenient food like bun to meet the requirement of daily allowances.

Conclusion

In order to utilize green leafy vegetables, a good source of easily available micronutrients apart from protein and dietary fiber, and also economic, buns were prepared using coriander and curry leaves as such and on dehydration. Quality characteristics of buns deteriorated with increasing levels of either NL or DL. Evaluation of buns indicated that addition of either 20 % NL or 5 % DL would be acceptable, beyond which the quality of buns were adversely affected. To improve the quality characteristics of buns different additives were used and acceptable quality buns were obtained with 25 % NL or 5 % DL. The buns from WF-WWF incorporated with either NL or DL had higher amounts of minerals, dietary fiber and carotenoids. Thus by blending WF with WWF and incorporating either NL or DL nutritionally rich buns could be prepared. These results indicate the scope for utilization of dehydrated leaves in products which would also supplement some of the micronutrients.

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