Chemical Science International Journal
19(1): 1-9, 2017; Article no.CSIJ.33348
Previously known as American Chemical Science Journal
ISSN: 2249-0205

SCIENCEDOMAIN *international*
www.sciencedomain.org

Effect of Formulations on Functional Properties and Storage Stability of Nutritionally Enriched Multigrain Pasta

Harsimran Kaur[1*], Hanuman Bobade[1], Arashdeep Singh[1], Baljit Singh[1] and Savita Sharma[1]

[1]Department of Food Science and Technology, Punjab Agricultural University, Ludhiana-141 004, Punjab, India.

Authors' contributions

This work was carried out in collaboration between all authors. Author HK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors HB and AS managed the analyses of the study. Authors BS and SS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CSIJ/2017/33348
Editor(s):
(1) Dimitrios P. Nikolelis, Chemistry Department, Athens University, Greece.
Reviewers:
(1) Muneer Saif Hasan Ahmed, University of Mysore, India.
(2) Celenk Molva, Izmir Institute of Technology, Turkey.
(3) Michael U. Ukwuru, Federal Polytechnic, Idah, Kogi State, Nigeria.
(4) Uma Ghosh, Jadavpur University, Kolkata, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/19017

Original Research Article

Received 11th April 2017
Accepted 8th May 2017
Published 11th May 2017

ABSTRACT

High fiber low gluten whole grain flours of wheat, barley, soybean, maize, millets, mungbean, oats and flaxseeds were blended in various proportions as a partial replacement for wheat flour along with Xanthan gum @ 2% for the development of nutritionally enriched pasta. Prepared pasta samples were assessed for cooking quality, color characteristics, sensory properties and selected samples were packed in HDPE bags and stored for 90 days and the stored samples were analyzed for changes in their moisture content, free fatty acids, water activity, cooking quality and overall acceptability at 30 days interval. Substitution of wheat flour by multigrain flour in pasta making significantly ($p<0.05$) increased the water absorption and volume expansion while it significantly ($p<0.05$) decreased the cooking time. The loss of solids in cooking water increased significantly ($p<0.05$) with the use of multigrain flour. Color characteristics and overall acceptability scores of

**Corresponding author: E-mail: simdhillon88@gmail.com;*

multigrain pasta were comparable with pasta made of wheat flour. Cooking quality of pasta was not significantly influenced by the 90 days storage period. Significant ($p<0.05$) increase in moisture content, water activity and free fatty acid was found during the 90 days storage. However, the changes in quality parameters during storage were well within the limit and in acceptable range.

Keywords: Pasta; multigrain; cooking quality; storage stability; overall acceptability.

1. INTRODUCTION

Pasta is a well known Italian food and its consumption is globally widespread. During the past decade, there has been tremendous increase in pasta based dishes at fast food chains and other restaurants which lead to an increase in the pasta production globally from 7 to 12 million tons/year. The aspiration for convenient and health based food has pushed the pasta industry to develop ready-to-eat, shelf-stable high quality pasta products [1].

The popularity of pasta products is increasing because they are simple to prepare, economical and can be stored after drying for a longer period without much deterioration in quality. Pasta products are traditionally manufactured from durum wheat semolina which is known to be the best raw material suitable for pasta production [2]. Pasta is a source of carbohydrates [3] but lacks in health protecting nutrients such as vitamins, minerals and phytochemicals. Consumption of refined cereal products (bread, pasta and rice) has been associated with an increased risk of digestive tract, pharynx, larynx and thyroid cancers [4].

There is growing evidence that whole-grain cereal products have various health benefits and provide protection against the development of several chronic diseases. The most important of these in terms of public health are obesity, the metabolic syndrome, type 2 diabete, CVD and cancers [5,6,7,8,9]. Because of the scientific data signifying the health benefits of various whole grains, the recommendation for whole grain consumption has been changed. The recommended consumption pattern of such cereal products varies from country to country [10,11]. Further, the recent research recognizes that the benefits of whole grain are not only because of their fibre content, but also due to other biologically active compounds and due to their synergistic effects of dietary fibre and micronutrients found in whole grain foods [12,13]. Industry has responded to the increased recommendation for whole grain consumption [14].

The current sedentary lifestyle and changed food habits of most population demands production of formulated foods such as pasta which can give many health benefits. Pasta is a good carrier to supply nutrition for the health conscious consumers. This provides better opportunity for preparation of high fiber nutritious pasta by use of different whole grain flours. However, substitution of wheat in pasta making with other grains may affect the structure and shape of the product due to inadequate development of gluten network. Hydrocolloids such as xanthan gum could be effectively used to overcome this challenge. Hence, this research was undertaken to develop and characterize the multigrain pasta by utilizing multigrains such as wheat (*Triticum durum*), maize (*Zea mays*), barley (*Hordeum vulgare*), pearl millet (*Pennisetum glaucum*), oats (*Avena sativa*), mung bean (*Vigna radiata*), soybean (*Glycine max*) and flaxseed (*Linum usitatissimum*) flour with addition of xanthan gum @ 2% in some formulations and storage stability of pasta was assessed.

2. MATERIALS AND METHODS

2.1 Materials

Wheat, Barley, Soybean, Maize and Millet of commercial variety were procured from Directorate of Seed, PAU, Ludhiana, India. Mungbean, Oats, flaxseed and xanthan gum (SDFCL Ltd.) were purchased from market, Ludhiana, India.

2.2 Multigrain Blend Formulation

The grains were cleaned by removing dust, dirt and broken on gyratory screen. The grains were washed with clean water and dried in a hot air over at 50±2 C to about 14% moisture content as determined by AACC method [15]. The cleaned and dried grains were grinded using lab scale super mill (Perten, Sweden) to an average particle size of 200-250µ. Based on the results of preliminary trials, the whole grain flours were blended in different proportions and total 7 formulations were prepared (C1 to C7) along with C0 which served as control as outlined in Table 1.

Table 1. Composition of multigrain formulated blend

Compositions	Ratio (%)	Multigrain content (g)								
		Wheat	Barley	Soy bean	Maize	Millet	Mung bean	Oats	Flax seed	Xanthan gum
C0	100:0	100	-	-	-	-	-			
C1	70:30	70	5	5	5	5	5	5	2	-
C2	70:30	70	5	5	5	5	5	5	2	2
C3	60:40	60	10	5	5	10	5	5	2	-
C4	60:40	60	10	5	5	10	5	5	2	2
C5	50:50	50	10	15	15	10		-		
C6	50:50	50	10	10	10	10	5	5	2	-
C7	50:50	50	10	10	10	10	5	5	2	2

2.3 Pasta Preparation

The multigrain blended flour (500 g multigrain) of each composition was mixed separately with 125 mL (25%) distilled water in the mixing chamber of pasta extruder (Le monferrina Masoero Arturo and C.S.N.C., Italy) for 10 min to distribute water uniformly throughout the flour particles. Macroni shaped pasta was prepared by subjecting the dough to cold extrusion using single screw extruder. A pasta die (No. 225) having a corrugated V type spots of 1.5 mm opening is used. The speed of blade cutter in front of pasta die was so adjusted to produce pasta of 5-7 cm length. The resulting pasta was subsequently dried in a hot air over at 50±2 C for 4 h. The dried pasta was packed in polyethylene bags and stored at 7 C until analysis.

2.4 Cooking Quality

Cooking time for pasta was determined according to AACC Method 66-50 [15]. Water absorption, volume expansion and gruel solid loss were determined following the standard methods [16].

2.5 Color

Color of dried pasta was measured using Hunter Lab colorimeter (MiniScan XE Plus). Color readings were expressed by Hunter values for L*, a* and b*. L* values measure black to white (0-100); +a = red, -a = green; +b= yellow, -b = blue.

2.6 Overall Acceptability

Overall acceptability of stored pasta was evaluated on the basis of sensory attributes (appearance, color, texture, stickiness, flavor and taste) by serving the cooked pasta to a panel (n=7) of semi-trained judges [17].

2.7 Storage Stability

Based on results of cooking quality characteristics and overall acceptability, three best pasta samples were selected and assessed for storage stability against control pasta (C0). The pasta samples were packed in high density polyethylene (200 µ) and stored at ambient storage conditions (temperature: 20-30℃, RH: 55-75%). The samples were evaluated for cooking quality characteristics, moisture content [15], water activity [16] and free fatty acid content [18] at 30 days interval.

2.8 Experimental Design and Statistical Analysis

Completely randomized design (CRD) was used to plan and execute the experiments [19]. All analyses were performed in triplicate and data is presented as mean ± standard deviation (SD) calculated with SPSS statistical software (Version 18.0, SPSS Inc., Chicago, IL, USA). Significant differences ($P \leq 0.05$) among different samples were verified with by one-way-analysis of variance (ANOVA) followed by Tukey's test at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Cooking Quality

Data in Table 2 displayed the cooking quality of multigrain pasta. Cooking time of pasta prepared with 100% whole wheat flour (C0) was 465±05 s which decreased progressively on addition of other grains in pasta making. Cooking time, as measured by squeezing the cooked sample between glass plates is representative of complete starch gelatinization. Addition of fiber rich grains and replacement of wheat gluten may have negatively affected the gluten network development in which starch is embedded and thus making starch more exposed to heat treatment and hence rapid gelatinization. Altered gluten matrix development due to presence of fibers in the formulation was reported [20]. Linear increase in cooking time of pasta with protein content was found [21]. Decrease in cooking time of pasta with increase in fiber source in the formulation was also observed [16]. Results further showed that addition of xanthan gum @ 2% in multigrain pasta blends increased the cooking time of pasta in comparison to the pasta prepared without xanthan gum. This shows that xanthan gum aids in development of system network which supports and binds starch and other ingredients firmly which therefore increase the cooking time.

Water absorption of pasta increased consistently with decrease in the amount of wheat and increased proportion of other grains in the formulation. This may be due to high affinity of fiber for water [22,23]. Moreover the water absorption of xanthan gum containing pasta over its counterpart sample was more. It was found that the volume expansion of pasta linearly related with the water absorption. Water absorption trend was well reflected in the volume expansion behavior of the pasta. Highest water absorption (195.14±5.75%) and volume expansion (1.89±0.12 ml/g) was observed for C7 formulation containing 2% xanthan gum. This connotation may be attributed to increased fiber content of the formulation. The results also confirm the potential of xanthan gum as hydrocolloid and its positive impact in pasta making.

Incremental addition of multigrain in blend formulation for pasta preparation, however, resulted in higher gruel solid loss. The gruel solid loss increased from 4.36±0.25% for pasta containing 100% wheat (C0) to 7.82±0.38% for pasta containing 30% wheat and 70% other grains without added xanthan gum (C6). Progressive addition of multigrain in pasta making lowered the protein content which developed weaker gluten network. In addition, the increased fiber content from multigrain may have hindered the gluten network development. This may have resulted in increased susceptibility of starch and other constituents for solubilization in hot water on cooking. The strength of gluten network is universally acknowledged to be an important condition for high quality pasta [24]. Release of significantly higher solids during cooking was noticed in formulation containing carrot fiber as a replacement for durum wheat flour [20]. Further, it was noticed that addition of xanthan gum lowered the loss of leached solids in cooked water. Pasta prepared with the formulation 70% wheat and 30% other grains with added xanthan gum (2% of the formulation) had low gruel solid loss (4.21±0.31%) than the control pasta (pasta with 100% wheat). Xanthan gum, due to its hydrocolloid nature may have shielded the starch and other constituents of pasta from being soluble by forming strong and firm network. These results are in agreement with other studies [25]. Increased cooking loss of pasta was observed when pea fiber and inulin were substituted to durum wheat flour [25].

3.2 Color

The color characteristics in terms of L*, a* and b* values of pasta samples are reported in Table 3. Lightness (L*) varied non-significantly from 53.2±2.71 for pasta sample prepared with 100% wheat flour (C0) to 42.4±4.44 for pasta sample prepared with 30% wheat and 70% other grains (C7). This decrease in lightness of the pasta samples by addition of multigrain and reduction of wheat proportion may be due to more amount of fiber and proportionately reduced starch and protein. Significant ($p<0.05$) reduction in L* value of carrot incorporated past was found [20]. Xanthan gum inclusion increased the whiteness

Table 2. Cooking quality of pasta from multigrain blends

Compositions	Cooking time (s)	Water absorption (%)	Volume expansion (ml/g)	Gruel solid loss (%)
C0	465±05^{a}	146.03±3.10^{e}	1.23±0.11^{c}	4.36±0.25^{e}
C1	355±05^{cd}	153.53±5.50^{de}	1.36±0.07^{bc}	5.56±0.22^{cd}
C2	390±10^{b}	161.92±7.82^{cde}	1.45±0.23^{bc}	4.21±0.31^{e}
C3	340±10de	158.76±3.93^{de}	1.41±0.19^{bc}	6.73±0.28^{b}
C4	380±15^{b}	166.14±5.84^{cd}	1.54±0.15^{abc}	4.87±0.35^{de}
C5	320±10^{e}	177.65±6.38^{bc}	1.63±0.09^{ab}	7.44±0.21^{ab}
C6	330±05^{e}	189.87±8.81^{ab}	1.72±0.07^{ab}	7.82±0.38^{a}
C7	375±05^{bc}	195.14±5.75^{a}	1.89±0.12^{a}	5.81±0.31^{c}

Values followed by the different letter within the column differ significantly (P<0.05) of pasta sample as compared to non-xanthan gum pasta samples, which may be attributed to translucent appearance formed as a result of network formed by xanthan gum and water held within it. Replacement of wheat by other grains in the pasta sample resulted in decreased redness (a* value) and yellowness (b*) and thus concurrently increased greenness and blueness, respectively. This may be due to reduction in starch and/protein by fiber addition. Increase in darkness as a function of bran addition in pasta was reported [16].

3.3 Storage Stability

Cooking time, water absorption and volume expansion decreased during storage of pasta samples of all formulations. Gruel solid loss, as expected, was found increased. Cooking time of stored pasta was decreased by 10, 15, 20 and 20 s for C0, C2, C4 and C7 formulation, respectively. More profound decrease in cooking time was observed in pasta formulation containing 50% wheat (Fig. 1a). Reduction in cooking time may be due to physical disruption of gluten matrix by germ and bran particles providing a path for water absorption [26]. Water absorption also progressively decreased as the amount of other grains in formulation increased (Fig. 1b). Pasta prepared with inclusion of multigrain showed drastic decrease in water absorption over the control pasta (100% wheat). The decrease in water absorption of control pasta was ca. 5% (data not reported). Expansion in volume of stored pasta on cooking was linearly related with water absorption. Effect of storage, alike cooking time and water absorption, also reflected in volume expansion of multigrain pasta (Fig. 1c). Storage of pasta augmented the leaching and loss of solids in cooked water,

Table 3. Color characteristics of multigrain pasta

Compositions	L*	a*	b*
C0	53.2±2.71^{a}	5.16±0.36^{a}	15.16±0.62^{a}
C1	47.0±3.53^{a}	3.10±0.32^{b}	11.64±0.55^{b}
C2	47.8±4.22^{a}	3.15±0.40^{b}	11.97±0.73^{b}
C3	44.4±3.84^{a}	2.83±0.35^{b}	10.41±0.68^{b}
C4	45.5±6.82^{a}	2.97±0.24b	11.22±0.98^{b}
C5	43.1±5.91^{a}	2.71±0.29b	10.59±0.82^{b}
C6	42.4±4.44^{a}	2.63±0.36^{b}	10.18±0.75^{b}
C7	43.5±2.95^{a}	2.75±0.39^{b}	10.83±0.59^{b}

Values followed by the different letter within the column differ significantly (P<0.05)

Table 4. Effect of storage period on quality characteristics and overall acceptability of multigrain pasta

Quality characteristics	Composition/Storage period (days)	0	30	60	90
Moisture content	C0	10.15±0.24^{a}	10.18±0.19^{a}	10.27±0.32^{a}	10.40±0.29^{a}
	C2	9.82±0.21^{b}	10.93±0.41^{a}	11.2±0.36^{a}	11.28±0.50^{a}
	C4	8.54±0.17^{a}	8.69±0.44^{a}	8.91±0.27^{a}	9.03±0.41^{a}
	C7	9.10±0.35^{b}	10.18±0.38^{ab}	10.23±0.46^{ab}	10.32±0.53^{a}
Water activity	C0	0.32±0.02^{b}	0.38±0.08^{ab}	0.45±0.05^{ab}	0.49±0.03^{a}
	C2	0.42±0.02^{c}	0.52±0.06^{bc}	0.61±0.01^{ab}	0.69±0.05^{a}
	C4	0.45±0.04^{c}	0.52±0.02^{bc}	0.62±0.02^{b}	0.70±0.07^{a}
	C7	0.43±0.03^{c}	0.50±0.05^{b}	0.63±0.02^{ab}	0.71±0.07^{a}
Free fatty acidity	C0	0.23±0.04^{a}	0.31±0.01^{a}	0.35±0.05^{a}	0.39±0.04^{a}
	C2	0.41±0.03^{c}	0.50±0.02^{b}	0.54±0.04^{b}	0.62±0.02^{a}
	C4	0.44±0.03^{c}	0.52±0.02^{bc}	0.56±0.03^{b}	0.66±0.06^{a}
	C7	0.47±0.03^{c}	0.62±0.04^{b}	0.69±0.08^{ab}	0.78±0.05^{a}
Overall Acceptability^{NS}	C0	8.26±0.10	8.30±0.21	8.35±0.20	8.30±0.11
	C2	7.65±0.11	7.68±0.14	7.70±0.24	7.75±0.15
	C4	7.79±0.20	7.81±0.10	7.85±0.16	7.84±0.20
	C7	7.60±0.15	7.67±0.18	7.70±0.10	7.75±0.10

Values followed by the different letter within the row differ significantly (P<0.05)
NS, Non-significant

however, the increase was very marginal (Fig. 1d). The changes in these cooking quality parameters were very small and non-significant (P>0.05). These changes in cooking quality may have been accredited to slight diminution of polymeric structure of stored pasta. Similar findings have been reported for wheat flour based macroni [27].

Pasta samples of all formulations during storage showed increase in the moisture content, water activity, free fatty acid and overall acceptability (Table 4). Moisture content, water activity, free fatty acid and overall acceptability of control pasta (C0) did not show significant (P>0.05) changes during storage for 90 days. These quality characteristics altered significantly (P≤0.05) for pasta prepared from other formulations (C2, C4 and C7) apart from control pasta. Moisture content of control pasta increased from 10.15±0.24% to 10.40±0.29% while that of pasta containing 50% wheat increased from 9.10±0.35% to 10.32±0.53% at the end of 90 days. Water activity of pasta increased linearly with the moisture content during storage. The significant (P≤0.05) increase in moisture content and water activity might be due to high temperature, relative humidity and/ high water vapor transmission rate of the packaging material used. The higher water activity of multigrain pasta compared to control pasta may be due to more fiber content which can hold greater amount of water on account of polymeric nature. Increase in water activity during storage of bran enriched pasta was reported [16].

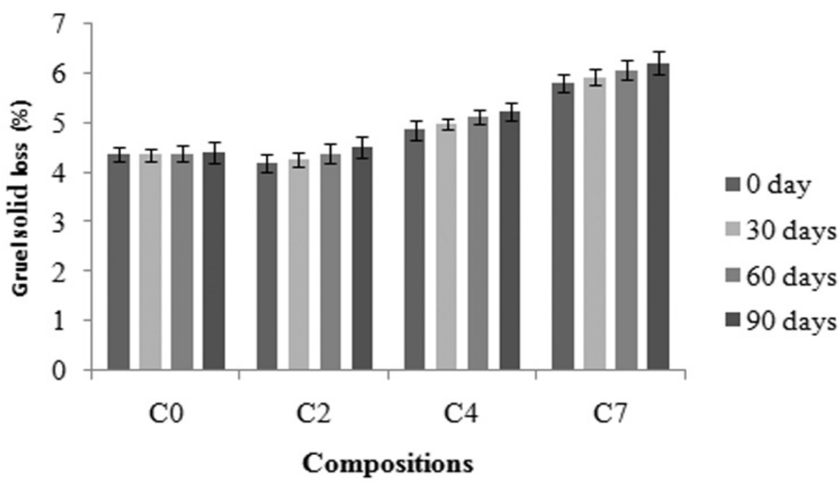

Fig. 1a. Effect of storage period on the gruel solid loss (%) of multigrain pasta

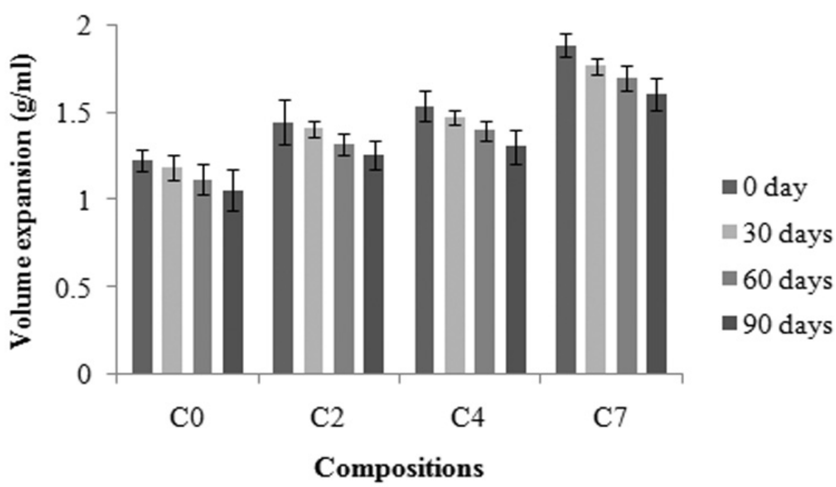

Fig. 1b. Effect of storage period on the volume expansion (g/ml) of pasta

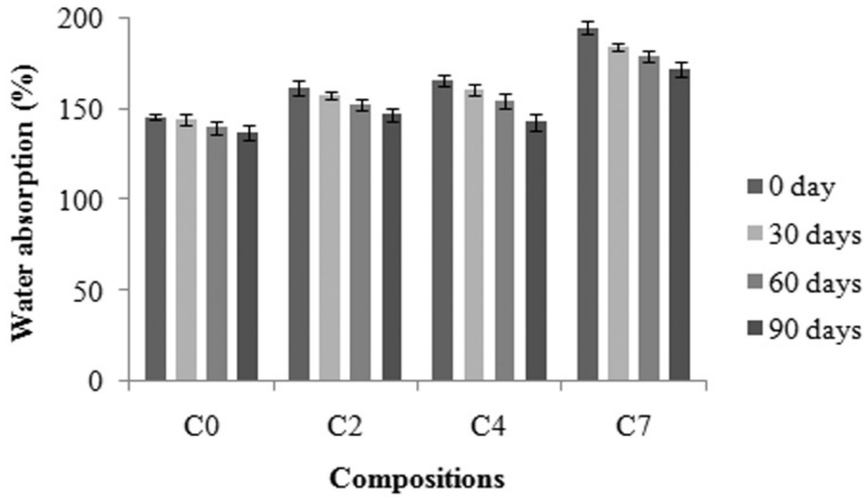

Fig. 1c. Effect of storage period on the water absorption (%) of pasta

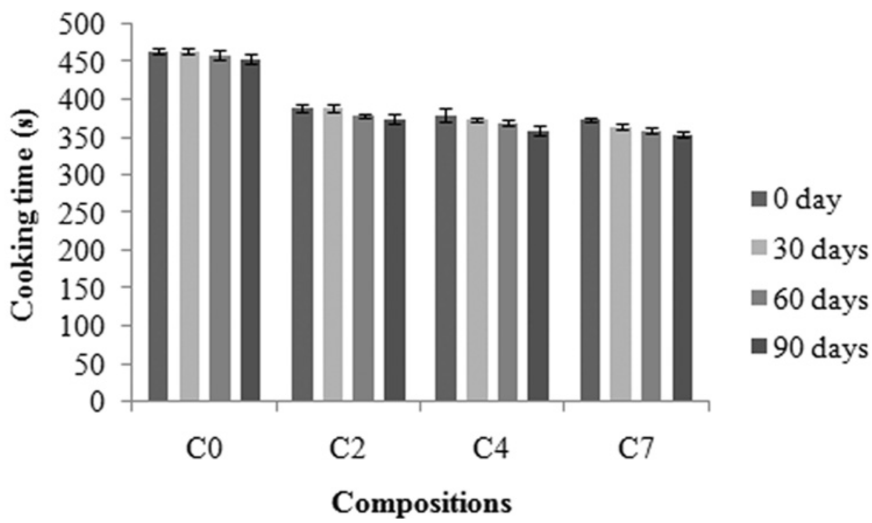

Fig. 1d. Effect of storage period on the cooking time (s) of pasta

Significant ($P \leq 0.05$) increase in free fatty acid content was observed in multigrain pasta containing 50% wheat and it reduced proportionately with increased wheat content in pasta formulation. This high fatty acid content may have been due to higher fat content in multigrain pasta than control pasta and its successive hydrolysis during storage influenced by moisture and temperature. Overall acceptability of pasta stored for 90 days ranged from 8.20±0.10 (100% wheat) to 7.05±0.15 (50% wheat). This shows that the pasta can remain in fairly acceptable range over 3 month storage period. Reduction in overall acceptability may have been mostly influenced by free fat acidity development as it produces rancid flavor in the product. Similar findings have been reported by researchers for various pasta products [16,28].

4. CONCLUSION

Cooking quality, color characteristics and sensory properties of pasta prepared by use of multigrain flours differed significantly from that prepared with 100% wheat flour. Pasta made of multigrain showed higher water absorption and volume expansion but it also leached more solids in cooked water than the pasta prepared with wheat flour alone. The multigrain pasta was slightly darker in appearance. The multigrain pasta could be stored safely for 90 days without excessive quality deterioration. Multigrain flour could be effectively utilized for high quality pasta which will increase the whole grain consumption and likely to reduce the risk of degenerative diseases. Nutritional studies focusing on bioactive composition of multigrain pasta will highlight and enhance the importance of substitution of wheat flour by multigrain flour in pasta making.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Carini E, Curti E, Cassotta F, Najm NEO, Vittadini E. Physico-chemical properties of ready to eat, shelf-stable pasta during storage. Food Chemistry. 2014;144:74-78.
2. Feillet P, Dexter JE. Quality requirements of durum wheat for semolina milling and pasta production. In Kruger JE, Matsuo RR, Dick JW, (eds). Pasta and noodle technology. American Association of Cereal Chemists, St. Paul, MN, USA. 1996;95.
3. Monge L, Cortassa G, Fiocchi F, Mussino G, Carta Q. Glyco-insulinaemic response, digestion and intestinal absorption of the starch contained in two types of spaghetti. Diabetes, Nutrition and Metabolism. 1999;3:239.
4. Chatenoud L, La Vecchia C, Franceschi S, Tavani A, Jacobs DR Jr, Parpinel MT, Soler M, Negri E. Refined-cereal intake and risk of selected cancers in Italy. American Journal of Clinical Nutrition. 1999;70:1107.
5. Koh-Banerjee P, Rimm EB. Whole grain consumption and weight gain: A review of the epidemio-logical evidence, potential mechanisms and opportunities for future research. Proceeding of Nutritional Society. 2003;62:25.
6. Esmaillzadeh A, Mirmiran P, Azizi F. Whole-grain consumption and the metabolic syndrome: A favorable association in Tehranian adult. European Journal of Clinical Nutrition. 2005;59:353.
7. Murtaugh MA, Jacobs DR, Jacob B. Epidemiological support for the protection of whole grains against diabetes. Proceeding of Nutritional Society. 20078;62:143.
8. Mellen PB, Walsh TF, Herrington DM. Whole grain intake and cardiovascular disease: A meta-analysis. Nutritional Metabolic Cardiovascular Disease. 2008;18:283.
9. Chan JM, Wang F, Holly EA. Whole grains and risk of pancreatic cancer in a large population-based case – control study in the San Francisco Bay area, California. American Journal of Epidemiology. 2007; 166:1174.
10. European Food Information Council (EUFIC). Whole grain fact sheet; 2009. Available:http://www.eufic.org/article/en/page/BARCHIVE/expid/Whole-grain-Fact-Sheet/
11. Lang R, Jebb SA. Who consumes whole grains, and how much? Proceeding of Nutrition Society. 2003;62:123.
12. Jacobs DR, Steffen LM. Nutrients, foods, and dietary patterns as exposures in research: A framework for food synergy. American Journal of Clinical Nutrition. 2003;78:508.
13. Koh-Banerjee P, Franz M, Sampson L, Liu S, Jacobs D, Spiegel-man D, Willett W, Rimm EB. Changes in whole-grain, bran, and cereal fiber consumption in relation to 8-y weight gain among men. American Journal of Clinical Nutritional. 2004;80: 1237.
14. Okarter N, Liu RH. Health benefits of whole grain phytochemicals. Critical Reviews in Food Science and Nutrition. 2010;50:193.
15. AACC. Approved Methods of American Association of Cereal Chemists. 10th edition (American Association of Cereal Chemists, St. Paul, MN); 2000.
16. Kaur G, Sharma S, Nagi HPS, Dar BN. Functional properties of pasta enriched with variable cereal bran. Journal of Food Science and Technology. 2012;49:467.
17. Larmond E. Methods for sensory evaluation of food (Can Department of Agriculture, USA); Pub No 1284; 1970.
18. AOAC. Official methods of analysis. 14th Edition (Association of Official Analytical Chemists, Arlington, VA); 2001.
19. Gomez AK, Gomez AA. Statistical procedures for agricultural research. John Wiley and Sons, New York, USA; 2010.
20. Carini E, Curti E, Spotti E, Vittadini E. Effect of formulation on physicochemical properties and water status of nutritionally enriched fresh pasta. Food Bioprocess Technology; 2010. DOI: 10.1007/s11947-010-0476-4

21. Bashir K, Averi V, Masoodi L. Physico-chemical and sensory characteristics of pasta fortified with chickpea flour and defatted soy flour. IOSR-JESTFT. 2012;1:34.
22. Chinachoti P. Water mobility and its relation to functionality of sucrose-containing food system. Food Technology. 1993;47:134.
23. Wang J, Rosell CM, Benedito de Barber C. Effect of the addition of different fibres on wheat dough performance and bread quality. Food Chemistry. 2002;79:221.
24. Ames NP, Clarke JM, Marchylo B, Dextel JE, Woods SM. Effect of environment and genotype on durum wheat gluten strength and pasta viscoelasticity. Cereal Chemistry. 1999;76:582.
25. Tudorica CM, Kuri V, Brennan CS. Nutritional and physicochemical characteristics of dietary fiber enriched pasta. Agricultural Food Chemistry. 2002;50:347.
26. Manthey FA, Schorno AL. Physical and cooking quality of spaghetti made from whole wheat durum. Cereal Chemistry. 2002;79:504.
27. Pinarch L, Lu EB, Oner MD. Effect of storage on the selected properties of macaroni enriched with wheat germ. Journal of Food Engineering. 2004;64:249.
28. Manthey FA, Sinha S, Wolf Hall CE, Hall CA. Effect of flaxseed flour and packaging on shelf life of refrigerated pasta. Journal of Food Processing and Preservation. 2008;32:75.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/19017