IJFANS
International Journal of Food And Nutritional Sciences

Volume 4, Issue 4, Jul-Sep 2015, www.ijfans.com e-ISSN: 2320-7876

INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

IMPACT FACTOR ~ 1.021

Official Journal of IIFANS

IJFANS International Journal of Food And Nutritional Sciences

INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

e-ISSN 2320 –7876 *www.ijfans.com*
Vol.4, Iss.4, Jul-sep, 2015

Research Paper *Open Access*

STANDARDIZATION OF EXTRUDED PRODUCTS USING MODIFIED MILLET FLOUR AND PULSE FLOUR

Thilagavathi. T*, Kanchana. S, Banumathi. P and Ilamaran. M
Department of Food Science and Nutrition, Home Science College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India.

*****Corresponding author: thilagavathiraj@gmail.com

Received on: 15th May, 2015 **Accepted on: 16th September, 2015**

ABSTRACT

The present study on influence of millet and pulse blend on rheological, cooking, nutritional and organoleptic characteristics of noodles prepared from composite flour of whole wheat flour, modified millet flour (kodo millet, pearl millet) and pulse flour (horse gram and soybean). The incorporation of millet and pulse flour increased the cooking characteristics such as cooked volume, water uptake, cooked weight and decreased gruel loss. The rheological properties like viscosity vs. shear rate were decreased. The nutritional components like protein, crude fibre, dietary fibre, minerals and phytochemical components were increased and carbohydrate, starch, amylose contents were decreased due to the incorporation level of modified millet flour and pulse flour respectively. The mean value for overall organoleptic scores of developed extruded products were highly acceptable and in the range of 8.8-8.4. The microbial population was within the safer limit during the storage period.

Keywords: Modified millet flour, pulse flour, noodles, rheological, cooking, nutritional, organoleptic characteristics

INTRODUCTION

In development of breakfast snack and variety products which are health and convenience plays a major role. At the same time strapped consumers had sparked the development of convenient and nutritious food products. Realizing the malnutrition problems of low-income group people and preschool children, the need of upgrading of nutrition is becoming a major concern. Pasta products, largely consumed all over the world were traditionally manufactured from durum wheat semolina, known to be the best raw material suitable for pasta production (Feillet and Dexter, 1996). Extrusion cooking of cereals is a very important process in food industry, since it regards a wide range of products such as snack-foods, baby-foods, breakfast cereals, noodle, pasta and cereals based blends. Extruders minimize the operating costs and higher productivity than other cooking process, combining energy efficiency and versatility (Ficarella *et al*., 2004).

Glycemic index could be attributed to development of resistant starch during heating and cooling cycles. Heating and cooling cycles significantly increased resistant starch fraction in millets. Resistant starch (defined as any starch that escapes digestion in small intestine) was reported to exhibit a wide range of health benefits such as lowering caloric density and low glycemic response. It was also reported to lower digestibility and act as a fecal bulking agent. The health benefits of RS have been reported as prevention of colon cancer, hypoglycemic effects, substrate for growth of the probiotic microorganisms, reduction of gall stone formation, hypocholesterolemic effects, inhibition of fat accumulation, and increased absorption of minerals. The potential health benefits of SDS are linked to a stable glucose metabolism, diabetes management, mental performance and satiety. Slowly digestible starch content was increased by autoclaving and cooling cycle method.

Millets contain rich sources of dietary fiber, micronutrients and phytochemicals with antioxidant activity (Singh *et al.*, 2012). It has also been reported that millet proteins are good sources of essential amino acids except lysine and threonine but are relatively high in methionine. Millets have been reported to be the rich sources of dietary fibre which is present as soluble and insoluble form is proved to play an important role in the management of metabolic disorders like diabetes mellitus, cardiovascular disease, hyperlipidemia, improve bowel motility and in turn reduce the incidence of colon cancer due to its low glycemic index and antioxidant activity (Hathan and Prasanna, 2011). They also have a several potential health benefits such as reducing tumor incidence, lowering blood pressure, cholesterol and rate of fat absorption, delaying gastric emptying and supplying gastrointestinal bulk have been reported for millet (Gupta *et al.*, 2012).

Legumes are an important source of food protein and other nutrients (Thakur and Saxena, 2000). Cereals have high level of sulphur-amino acid such as methionine but deficient in lysine while in legumes the level of sulphur-amino acid is low but rich in lysine. So the high lysine and low sulphur-amino acids in legumes could suitable to fortify millet products (WHO, 2005). Horse gram contains good sources of protein, crude fibre, carbohydrate and minerals. The high content of dietary fibre in horse gram helps in reducing the body fat and is extremely useful in the management of diabetes mellitus, atherosclerosis, colon cancer, ischaemic heart disease, gallstone, diverticulosis, hypertension and constipation (Sreerama *et al.*, 2012). Soybeans are widely recognized by medical and health professionals for their health benefits. Soybeans protein has been found to reduce the risk of coronary heart disease when consumed as part of a diet low in saturated fat and cholesterol (Tripathi and Misra, 2005). Egg protein is widely considered as the highest nutritional quality protein of all food sources, providing all the essential amino acids in amounts that closely match human requirements (Chernoff, 2004).

Pasta products are high in starch but low in protein, dietary fibre, vitamins, minerals, phenolic compounds and are mainly made up of hard wheat flour which is deficient in lysine. Now a days, it has become important to improve the quality of pasta by the addition of other ingredients. Hence flour blends composed of whole wheat flour, modified millet flour, pulse flour and egg albumen were used to develop low glycemic functional pasta which are rich in proteins with high biological value, vitamins, minerals, dietary fibre and phytochemical compounds.

MATERIALS AND METHODS

Whole wheat, kodo millet (CO 3) and pearl millet (COC 9) were collected from Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore. Horse gram and soybean was collected from local departmental store.

OPTIMIZATION TECHNOLOGY FOR THE DEVELOPMENT OF MODIFIED STARCH FROM MILLETS:

To optimize the technology for the development of modified starch to utilize millets as the functional food ingredient, the physical modification method has been followed.

PHYSICAL MODIFICATION (AUTOCLAVING-COOLING CYCLE)

The physical modification (autoclaving - cooling cycle method) technique was used and followed as per the standard Berry (1986) procedure for the preparation of modified starch (kodo millet, little millet and pearl millet) with slight modification. The kodo millet and pearl millet grains were cleaned, washed separately and soaked for 2 hours, ground and then it was pressure-cooked at 121˚C (15 lb / in^2) for one hour in an autoclave. The gelatinized starch mixture was cooled to room temperature and it was frozen at 4^{o}C for 24 hours which was termed as one cycle. Then, three additional cycles were carried out, followed by cabinet - drying for about 4-6 hours at 40^{o}C according to the respective starches and ground into fine particles and packed in air-tight container.

PREPARATION OF FLOUR

Millets and pulses were ground and sieved through BS No. 60 mesh sieve (British Sieve Standards) to obtain uniform particle size of the flour. The flour samples were defatted by solvent extraction process using petroleum ether (60 - 80^{o}C) and dried at a temperature of 50°C for 5 hour in a hot air oven and then packed in air-tight container after cooling.

RHEOLOGICAL PROPERTIES OF EXTRUDED FUNCTIONAL FLOUR BLENDS

The rheological characteristics of functional flour blends were analyzed by using rheometer as per the method Bhattacharya and Bhat (1997). A rheometer (CSR 1, Anton Paar and Germany) with a parallel plate assembly was used to analyze the rheological behavior of the prepared extruded flour blends samples. The rheological data analysis was performed using Rheoplus/32V3.61 software.

OPTIMIZATION OF MILLET AND PULSE BASED EXTRUDED PRODUCTS

The various treatments of whole wheat flour with combinations of modified millet flour and pulse flour was carried out in various proportions to formulate low glycemic extruded products. The process for development of extruded noodles with cereal millet and pulse is given in Table 1. Hundred grams of functional flour blend was added with hot water (70ºC) and mixed well. Then, it was steamed in an idly steamer for 15 minutes. The steamed functional flour blend was fed in the barrel of extruder. Then, the blend was moistened with hot water (70ºC) and they were mixed thoroughly in the extruder by the shaft in the extruder. The mass was allowed to knead for 15 minutes to ensure thorough distribution of moisture. The appropriate die for respective product was fixed and then extruded. After extrusion, the extruded products were steamed for 20 minutes using idly steamer. The steamed extruded products were then cooled and dried in cabinet drier for four hours at 60°C.

Table 1: Proportions to formulate extruded noodles

Treatments	Whole wheat flour (%)	Kodo millet flour (%)	Pearl millet flour (%)	Horse gram flour (%)	Soybean flour (%)	Egg white (%)	Guar gum (%)	Water (ml)	Salt (g)
T_1 (Control)	90	-	-	-	-	10	2	50	2
T_2	50	15	15	10		10	2	75	2
T_3	50	15	15	-	10	10	2	75	2

COLOUR

Colour measurements (L*a*b* values) of the noodles were determined using a Hunter laboratory chromometer (Model # Lovibond RT 100) with the Lovibond RT colour software (Version 3.0). Colour of noodles was measured by using Hunter Lab Colorimeter. Hunter lab calorimeter value *L** (0=black, 100=white), *a** (+value = red, -value = green) and *b**(+value = yellow, -value = blue) values were recorded.

COOKING CHARACTERISTICS OF NOODLES

The cooking characteristics of the developed noodles was measured by the cooking time, cooked weight, cooked volume, water uptake and cooking loss**.**

NUTRIENT ANALYSIS

Low glycemic noodles were analyzed for moisture (AOAC, 1995), carbohydrates (Dubois *et al.*, 1956), crude protein (Micro kjeldahal, Nx6.25), crude fat (solvent extraction), fiber (Maynard, 1970), starch and amylose (Sadasivam and Manickam, 2008). Minerals were determined by the method described by Jackson (1973). Soluble, insoluble and total dietary fiber was quantified by Hellendoorn technique (James and Theander, 1981). Total polyphenols (Sadasivam and Manickam, 2008) and total antioxidant activity was carried out using DPPH assay (Goupy *et al.*, 1999).

SENSORY QUALITY

Noodles were evaluated for their sensory attributes by a panel of 20 untrained judges using 9 point hedonic scale (Watts *et al*., 1989). The mean scores of sensory attributes viz. External properties (colour and appearance), internal properties (texture) and taste properties (aroma and taste) were recorded.

MICROBIAL POPULATION

The microbial load of the kodo millet, little millet and foxtail millet incorporated extruded products were enumerated by the method described by Istavankiss (1984).

STATISTICAL ANALYSIS

The data are presented as mean ± SED of three replicates. The nutritive values of bread were subjected to Analysis of variance (ANOVA) to distinguish the responses of different levels of substitution and performed using Completely Randomized Design (CRD). The levels of significant differences are reported as $p \leq 0.05$.

RESULTS AND DISCUSSION

The values of yield stress, flow behavior index, fluid consistency index and the regression coefficient are depicted in Table 2. Steady and dynamic shear rheological properties of the extruded flour blend dispersions indicated that millet and pulse flour blends at the temperature of 37°C showed a shear-thinning fluid exhibiting a yield stress. Extruded flour blends demonstrated higher flow behavior index (n), and lower fluid consistency index (k) and yield stress. The magnitudes of yield stress, consistency index and apparent viscosity increased with an increase in concentration. Samyapriya *et al.* (2014) similarly reported that the extruded products prepared from rice flour dough.

Fig. 1 depicts the plot of shear stress (Pa) vs. shear rate (s-1) and viscosity vs. shear rate respectively, obtained for the prepared extruded flour blends samples. It was determined that shear stress of the samples (Pa) increased with increase in shear rate (s) at the temperature of 37°C. Thus, all the prepared dough samples depicted shear thinning behavior (pseudoplastic). For the pseudoplastic materials, as the shear stress increases the viscosity decreases as a result of the disruption of interactions between the components (Malkin and Isayev, 2006). Thus, all the batter samples demonstrated shear-thinning behavior (Yu, 2013). Also, it can be seen that viscosity decreased with increased in shear rate. This behavior was consistent in all the batter samples. This reflected lower batter viscosity (Chen *et al.*, 2008), resulting in easier hand extrusion when preparing *kurdi*.

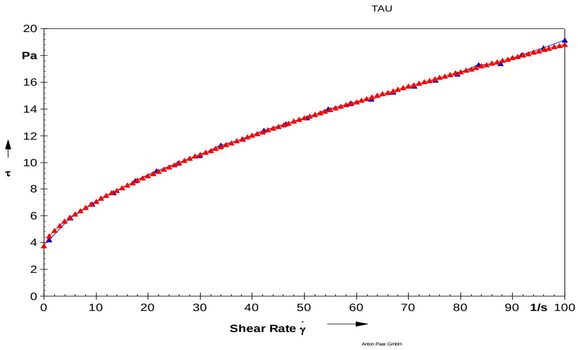
Table 2: Rheological characteristics of functional flour blend

Treatments	Flow behavior index (n), no unit	Fluid consistency index (k), Pa.s	Yield stress (Pa)	R^2
T_1	0.65743	0.72922	3.7777	0.99876
T_2	0.37763	4.6975	0.1514	0.99823
T_3	0.42283	4.0272	0.0000	0.99904

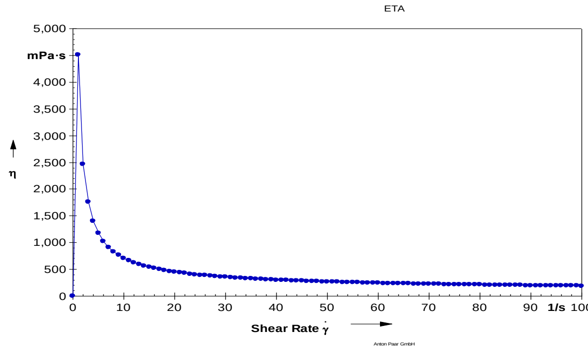
Table 3: Cooking characteristics of extruded products (noodles)

Cooking characteristics		T_1		T_2		T_3		CD (0.05)
		P_1	P_2	P_1	P_2	P_1	P_2	
Cooking time	I	6.00	6.00	6.00	6.00	6.00	6.00	0.071**
	F	4.15	4.20	4.25	4.30	4.30	4.35	
Cooked volume	I	161.49	161.49	176.28	176.28	177.05	177.05	0.390**
	F	170.28	169.80	184.17	183.85	187.36	186.95	
Cooked weight	I	165.70	165.70	189.50	189.50	185.62	185.62	0.421**
	F	235.95	234.75	251.68	250.78	241.78	240.87	
Water uptake	I	208.00	208.00	216.97	216.97	217.65	217.65	0.777**
	F	225.67	222.45	233.57	230.35	236.70	234.35	

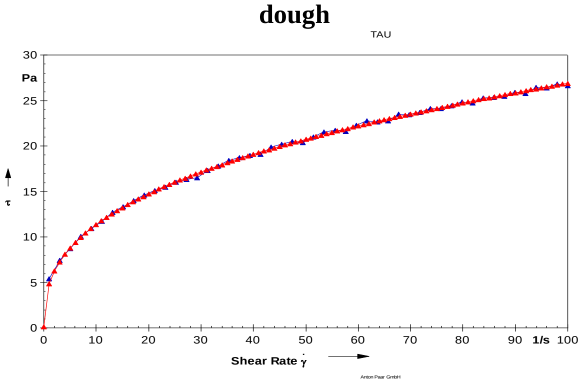
Cooking loss	**I**	0.27	0.27	0.15	0.15	0.17	0.17	0.040**
	F	2.38	2.30	2.31	2.30	2.46	2.45	
Rehydration ratio	**I**	2.39	2.39	2.45	2.45	2.49	2.49	0.045**
	F	4.00	3.89	4.18	4.10	4.24	4.15	



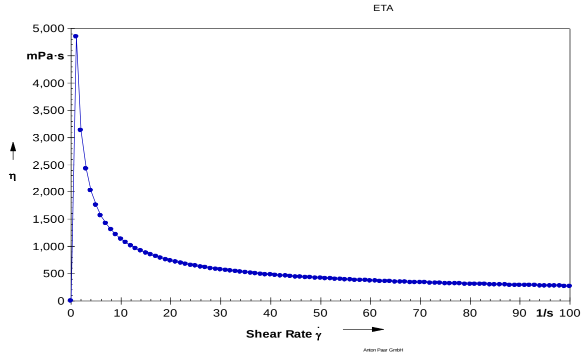
T_1 - Shear stress vs. shear rate of wheat flour dough



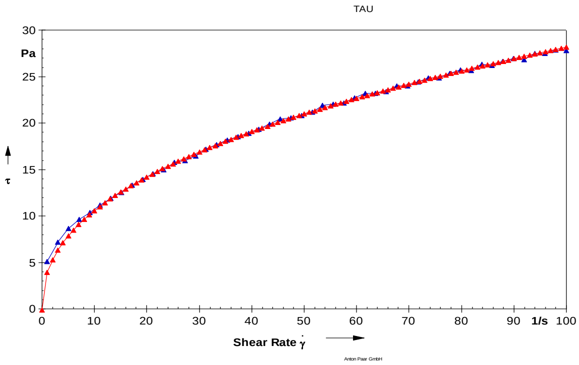
Viscosity vs. shear rate of wheat flour dough



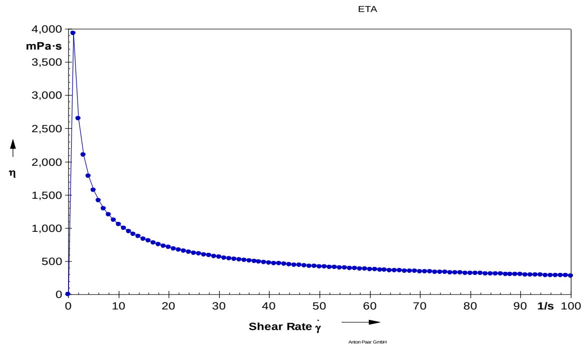
T_2 - Shear stress vs. shear rate of millet and pulse flour blends



Viscosity vs. shear rate of millet and pulse flour blends



T_3 **- Shear stress vs. shear rate of millet and pulse flour blends**



Viscosity vs. shear rate of millet and pulse flour blends

Fig. 1 Plot of shear stress (Pa) vs. shear rate (s-1) and viscosity vs. shear rate of extruded flour blends samples.

COOKING CHARACTERISTICS OF NOODLES

Cooking characteristics of noodles are given in Table 3. During cooking, the product should maintain its form without disintegration, increase substantially in volume, exude minimal material into cooking water and exhibit tolerance to over cooking. Good quality pasta is defined to have high degree of firmness and elasticity and during cooking; the product maintain its form without disintegration. Proper evaluation of pasta cooking quality requires consideration of a number of factors including surface stickiness, cooking tolerance, water absorption and loss of solids to cooking water (Sozer *et al.*, 2007). Initially the cooking time of noodles was 6.0 minutes in all the treatments. The time taken for cooking of noodles increased with increase in the level of incorporation of millet and pulse flour than the whole wheat flour. Observations indicated that the increase in the cooked volume and water absorption depends on the fiber and protein content in the pasta products. Increase in cooked volume was noted in millet and pulse blended noodles than control samples.

The results revealed that T_2 and T_3 samples showed a higher cooked weight, this could be due to the millet and pulse flour incorporation which are positively related to improved fiber and protein content of the samples. The cooking loss of control pasta was found to be higher than that of the experimental samples. The cooking loss of the pasta could be explained by the easier disruption of the protein network during the cooking process. The protein matrix usually disintegrates continuously, releasing exudates during starch granule gelatinization, which results an increase in cohesiveness and stickiness on the surface of the cooked pasta (Tudorica *et al*., 2002). Solid loss have been delayed due to the addition of food additive (10% egg albumen and 2% guar gum) which could help to maintain and strengthen the pasta structure during cooking and contributed to the low solid loss of experimental samples.

NUTRITIONAL COMPOSITION OF NOODLES

Nutritional compositions of noodles during storage are presented in Table 4. Protein, fat, fibre, ash and mineral contents were increased with increased level of incorporation of millet and pulse flour. Similarly protein, fat and fibre content of extruded products increased and ranged from 18.20 to 18.37 per cent, 8.76 to 9.26 per cent, 9.72 to 10.98 per cent in millet and soybean extruded products. The increase in mineral composition is possibly due to addition of germinated millet flour and roasted soybean flour (Abdoulaye *et al.,* 2012). Sugars and starch content of noodles are given in Table 5. Total carbohydrate, total sugar, starch, amylose were reduced with increased in the level of incorporation millet and pulse flour. Abdoulaye *et al.* (2012) stated that carbohydrate content of extruded products ranged from 63.62 to 64.34 per cent in millet and soybean extruded products. Similar increase in carbohydrate, total sugar, starch, amylose and amylopectin content were also observed by Poongodi *et al*. (2010) when incorporated millet flour noodles. Highly significant difference was noted for extruded noodles at 5% level ($p \leq 0.05$) in treatment, packaging and storage. Phytochemical components of noodles are given in Table 6. Total polyphenols, antioxidant activity, soluble fibre, insoluble fibre and total dietary fibre, content of noodles were observed to be high when compared to control samples due to the incorporation of modified millet flour and pulse flour. Jorge *et al*. (2012) stated that polyphenols and antioxidant activity of amaranth flour incorporated extruded products as 69.50 mg GAE /100g and 44.10 mg Trolox equivalent (TE)/100 g sample. Dipika *et al.* (2013) found that phenolics content of the multigrain mixes made from cereals, millets and sprouted pulses ranged from 103.5 to 115.0 which increased on sprouting to 121.7-139.7 mg GAE/100g. Alexia *et al.* (2007) found that the total dietary fibre content of pasta products made with 100 per cent semolina and semolina supplemented with germinated pigeon pea flour contained 4.73 ± 0.05 and 5.56 ± 0.58 per cent respectively.

The organoleptic characteristic is of great importance from the point of product acceptability by the consumers and the results of the study are given in Table 7. The standardized noodles exhibited smooth and firm texture with elasticity and less stickiness. The taste of the pasta products exhibited typical pasta. The mean value for overall organoleptic scores of developed extruded products were highly acceptable and in the range of 8.8-8.4.

Table 4: Nutritional composition of noodles during storage (Per 100g)

Nutrients		T_1		T_2		T_3		CD (0.05)
		P_1	P_2	P_1	P_2	P_1	P_2	
Moisture (%)	**I**	5.48	5.48	5.63	5.63	5.66	5.66	0.038**
	F	7.47	7.23	6.85	6.73	6.78	6.62	
Protein (g)	**I**	13.42	13.42	18.98	18.98	20.72	20.72	0.023**
	F	12.57	12.60	17.58	17.61	19.65	19.69	
Fat (g)	**I**	1.31	1.31	1.60	1.60	3.05	3.05	0.022 **
	F	0.78	0.71	1.10	1.07	2.38	2.41	
Fibre (g)	**I**	2.81	2.81	4.95	4.95	4.88	4.88	0.021**
	F	2.79	2.80	4.92	4.93	4.85	4.86	
Carbohydrate (g)	**I**	60.98	60.98	54.56	54.56	50.62	50.62	0.048**
	F	59.60	59.51	53.30	53.20	49.35	49.26	
Ash (g)	**I**	2.58	2.58	2.87	2.87	2.91	2.91	0.023NS
	F	2.57	2.57	2.86	2.86	2.90	2.91	
Calcium (mg)	**I**	51.70	51.70	180.65	180.65	150.76	150.76	0.602NS
	F	51.68	51.69	180.64	180.65	150.75	150.76	
Phosphorous (mg)	**I**	310.48	310.48	347.18	347.18	384.59	384.59	0.846NS
	F	310.47	310.48	347.15	347.17	384.58	384.59	
Iron (mg)	**I**	5.86	5.86	6.66	6.66	6.75	6.75	0.034NS
	F	5.85	5.86	6.65	6.65	6.74	6.75	
Copper (mg)	**I**	2.07	2.07	2.38	2.38	2.35	2.35	0.543NS
	F	2.06	2.07	2.37	2.38	2.34	2.35	
Zinc (mg)	**I**	5.39	5.39	5.86	5.86	5.87	5.87	0.030NS
	F	5.38	5.39	5.85	5.85	5.86	5.87	

**Significant at 5% level, NS – Non significant, I-Initial, F-Final, T_1- Whole wheat flour (Control), T_2- whole wheat flour & modified flour (kodo millet flour, peral millet flour, horse gram flour & egg albumen) T_3 - whole wheat flour & modified flour (kodo millet flour, pearl millet flour, soya flour & egg albumen), P_1- 200 gauge high density polyethylene bag, P_2 - Metallized polypropylene bag

Table 5: Sugars and starch content of noodles during storage (Per 100g)

Nutrients		T_1		T_2		T_3		CD (0.05)
		P_1	P_2	P_1	P_2	P_1	P_2	
Total sugar	I	5.29	5.29	4.56	4.56	4.73	4.73	0.044**
	F	4.68	4.75	3.92	3.98	4.27	4.35	
Reducing sugar	I	1.72	1.72	1.79	1.79	1.89	1.89	0.035**
	F	2.11	2.05	2.19	2.16	2.35	2.31	
Starch	I	50.76	50.76	37.92	37.92	36.58	36.58	0.088**
	F	50.00	50.16	37.14	37.18	35.85	35.91	
Amylose	I	20.25	20.25	16.34	16.34	15.45	15.45	0.033**
	F	20.52	20.51	16.63	16.60	15.82	15.81	
Amylopectin	I	30.51	30.51	21.58	21.58	21.13	21.13	0.045**
	F	29.48	29.65	20.51	20.58	20.03	20.10	

Table 6: Dietary fibre and phytochemical components of noodles (Per 100g)

Nutrients	T_1	T_2	T_3
Soluble dietary Fiber	2.47 ± 0.05	3.31 ± 0.13	3.34 ± 0.14
Insoluble dietary fiber	6.12 ± 0.20	8.55 ± 0.17	8.46 ± 0.23
Total dietary fiber	8.59 ± 0.15	11.86 ± 0.34	11.80 ± 0.52
Total polyphenols (mg GAE/100g)	95.00 ± 2.83	142.96 ± 3.61	138.69 ± 4.50
Antioxidant activity (mg AAEAA/ 100g)	7.73 ± 0.09	21.46 ± 0.77	21.74 ± 0.24

All data are the Mean ± S.D of three replicates

Table 7: Organoleptic characteristics of noodles during storage

Nutrients		T_1		T_2		T_3	
		P_1	P_2	P_1	P_2	P_1	P_2
Colour	I	8.8	8.8	8.7	8.7	8.7	8.7
	F	8.6	8.6	8.4	8.5	8.5	8.5
Flavor	I	8.7	8.7	8.7	8.7	8.7	8.7
	F	8.2	8.3	8.1	8.2	8.2	8.2
Texture	I	8.7	8.7	8.7	8.7	8.7	8.7
	F	8.2	8.3	8.2	8.2	8.2	8.2
Taste	I	8.8	8.8	8.8	8.8	8.8	8.8
	F	8.4	8.5	8.6	8.6	8.5	8.5
Overall acceptability	I	8.8	8.8	8.7	8.7	8.7	8.7
	F	8.4	8.4	8.3	8.4	8.4	8.4

MICROBIAL POPULATION

The microbial load of the noodles was found to increase during the storage period in different packaging materials. Initially the total plate count for control and millet and pulse incorporated noodles was below 1.00. Among the packaging materials metallized polypropylene pack (P_2) samples showed low microbial population and was found to be within the safer limits.

CONCLUSION

Based on the cooking characteristics, sensory and nutritional characteristics of the millet and pulse incorporated noodles, 30% millet flour, 10 % pulse flour and 10% egg albumen incorporation of level was found to be highly acceptable. The protein, fat, fibre, calcium, phosphorous and iron content of the millet and pulse incorporated noodles was higher than the whole wheat flour noodles. The microbial load was found to be within the safer limit.

ACKNOWLEDGEMENT

Tamil Nadu State Council for Science and Technology, Ministry of Food Processing, Chennai.

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