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Development of Millet Fortified Cold Extruded Pasta and Analysis of Quality Attributes of Developed Pasta Products

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Abstract:
The present study was undertaken to develop millet fortified cold extruded pasta products and to study the quality attributes of the developed products. Four pasta samples with different ratios of wheat flour to millet flour (1:0, 8:1, 4:1 and 2:1) were prepared using a single screw pasta extruder. The fresh extruded pasta samples were dried in an axial flow hot air tray dryer at 50°C for 2 hours to reduce the moisture content to 10-12 % wet basis. The fresh and dried pasta were analyzed for moisture content, colour, physical, cooking, textural. Three replications for each sample were followed. The average moisture content of fresh and dried pasta were found out to be 31.73±1.01 % wb and 11.84 ± 1.01 % wb respectively. The moisture content of the market sample was found to be 12.23 % wb. Average specific length of the developed millet fortified pasta products was found to be 27.70 ± 0.99 mm and average sectional expansion ratio was 0.91 ± 0.006. The bulk density of developed pasta varied between 281.71±3.42 and 301.88±16.17 kg.m-3 and average bulk density of the developed pasta and millet proportion are negatively correlated with correlation coefficient of 0.987 and R2 value of 0.976. A decreasing trend in desirable b values (yellowness) was observed with increase in millet flour content. Highest value of 1.16±0.09 of water absorption ratio was found for sample with 2:1 ratio of wheat to millet flour and lowest value of 0.81±0.07 was obtained for the sample with ratio 1:0. An increase in water absorption ratio with increase in millet flour content in pasta samples was observed with correlation coefficient of 0.971 and R2 value of 0.945 whereas cooking loss was slightly negatively correlated with correlation coefficient of 0.565 and R2 value of 0.319. Highest firmness (205.73N) was observed for sample with ratio 4:1 (S3) followed by samples with 2:1 (S4), 8:1(S2), 1:0 (S1).*

Keywords: *Pasta, millet, cold extrusion, firmness, cooking quality*

1. Introduction

Pastas (alimentary pastes) are among the simplest cereal products used in human diet. These include foods such as spaghetti, macaroni, vermicelli, and noodles. Pasta is a cold extruded product. In addition to dried pasta with or without egg, there are fresh, frozen and microwavable pastas, instant pastas, retortable pasta, etc., available to consumers (Giese 1992). Pastas are generally made by mixing wheat semolina (100% *Triticum durum* wheat) with minimum water to form unleavened wheat dough. Marchylo and Dexter (2001) reported 100 percent durum wheat semolina as the main ingredient of premium quality pasta. Semolina, which originates from the endosperm of durum wheat, is essentially coarse flour. Good quality pasta can also be made with durum wheat flour or a blend of semolina and durum wheat flour (granular). Other starchy foods and local cereals can also be used instead of wheat. Millet flour, spinach powder, tomato powder, egg, vitamins (thiamine, riboflavin, niacin) and minerals (iron) can also be included in some specialty pastas to develop fortified pasta products. Zardetto and Dalla Rosa (2009) prepared the fresh pasta by mixing, durum wheat semolina (76%w/w;12+1% protein dry mass(dm), pasteurized fresh egg(19%w/w), and water (5% w/w). Chillo et al. (2008) investigated the influence of the addition of buckwheat flour and durum wheat bran on spaghetti quality by comparing spaghetti made only of durum semolina. Their study suggested that the breakage susceptibility decreases with the addition of 15% and 20% bran, and the spaghetti dry colour changes with the addition of buckwheat flour and bran compared to the spaghetti made only of durum semolina, while the cooking resistance, instrumental stickiness and the cooking loss, in general, were equal to that of the control sample. However, the addition of buckwheat flour and bran affected the sensorial attributes differently. Miche et al. (1977) made pasta from mixtures of sorghum with wheat. They found that to obtain products of good cooking quality it was necessary to add some gelatinized starch to the sorghum flour before extrusion. The pasta quality is influenced by the quality of both the sorghum flour and the starch. White sorghum is preferable for pasta products as its colour is similar to that of wheat flour. A composite flour consisting of 70 percent wheat and 30 percent sorghum produced acceptable pasta. Noodles made with 20 percent prove millet flour were acceptable (Lorenz and Dilsaver 1980). The reduction of flour mass during cooking (cooking loss) at this level of addition was similar to that of wheat noodles used as a control. Cooking loss increased with 40 or 60 percent millet flour. Faure (1992) made pasta from mixtures of sorghum, millet and wheat. He found that the quality of the pasta was strongly related to the characteristics of the flour that was used and particularly to the way the flour was dried. There should be less than 1 percent ash and 1 percent fat in any material that is used. Limroongreungrat and Huang (2005) worked on production of pasta products made from sodium hydroxide solution treated sweetpotato fortified with soy protein**.** Petitot et al. (2010) worked on fortification of pasta with split pea and faba bean flours to produce nutritionally enhanced spaghetti by adding high amounts (35% db) of legume flour (split pea or faba bean) to durum wheat semolina. Torres et al. (2007) reported the use of germinated *Cajanus cajan* seeds (for 4 days at 20 °C in darkness) as ingredients in pasta products. They concluded that the supplemented pasta products had shorter cooking time and higher water absorption, cooking and protein losses in water than had control pasta (100% semolina). Nutritionally enhanced spaghetti was prepared from durum semolina fortified with 0–30% desi chickpea 'besan' flour by Wood (2009**).** The major findings were: gluten content/composition appears to be more important than protein content for pasta firmness; the protein–polysaccharide matrix appears to be more important than the starch composition for cooking loss; increased protein and amylose contents were associated with decreased pasta stickiness; cooking loss and stickiness were not necessarily as strongly related as commonly believed. Ovando-Martinez et al. (2009) used unripe banana flour as a food ingredient to make pasta (spaghetti) of high quality, on the basis of low-carbohydrate digestibility, and increased resistant starch and antioxidant phenolics contents.

Millets are small seeded hard annual cereal grains which are not only nutritionally comparable but also superior to major cereals with respect to protein, energy, vitamins and minerals. Besides they are rich source of dietary fibre, phytochemicals, micro-nutrients, nutraceuticals, and hence nowadays they are rightly termed as nutricereals (Desikachar 1997). The nutritive value of millets is comparable to other staple cereals like wheat and rice, and some millets are even better with regards to average protein, fat and mineral content (Gopalan et al. 1999). Extrusion processing is suitable for the production of fibre rich foods (Lue et al. 1991).

Millets in India occupy 0.7 percent of the total cropped area which is about 1.3 million hectares confining to the vast stretches of dry land and hilly area (IASRI 2006b). It is one of the underutilized cereal crops of North East India. The major use of millet in these regions is production of alcoholic beverage due to its difficulty in processing. In these regions, it is mostly grown in high altitude area and it is hardly used for food purposes. So, there is good scope of utilizing this cereal in value added products viz., pasta, noodles etc. Development of millet fortified cereal products will enhance the nutritional characteristics of processed products in terms of dietary fibre and micro-nutrients. Hence, keeping in views of the above facts, the present study was planned with the objective to develop millet fortified cold extruded pasta products and to study the quality attributes of the developed products.

2. Materials and Methods

2.1. Raw Material

Wheat flour (Amrit bhog) and kodo millet (*Paspalum scorbiculatum)* were used in the present study as the key ingredients of pasta. Millet was ground in a laboratory hammer mill (ICT, India) to an average particle size of 250 micron. Similarly, the wheat flour was also sieved to obtain the particle size of 250 micron. Macaroni (MTR) was also purchased from local market to be used as control sample.

2.1.1. Analysis of Raw Materials

Moisture content both wheat flour and millet flour were measured by oven drying method using hot air oven (ICT, India) at 102°C for 24h as per the standard procedure given in AOAC (1997).

Preparation of Pasta

Four pasta samples with different proportion of wheat flour and millet flour were prepared for the present study. The ratios of wheat flour to millet flour varied between 1:0 and 8:1. The details of the levels of wheat and millet flour are given in Table 1. The wheat flour and millet flour were mixed in different proportions in the mixing chamber of pasta extruder for about 15 minutes by intermittent addition of water. The final moisture content of dough for pasta production was adjusted to 30 to 33% wet basis (wb) by addition of required quantity of water to wheat and millet flour mixture. After mixing, extrusion was carried out at a fixed speed of 54 rpm in the pasta extruder. A die of 10 mm diameter was used for the present study. The extruded pastas coming out of the die were cut to desired length by the cutter of the pasta extruder. Pasta was prepared in 0.5 kg/batch. The four pasta samples were dried in an axial flow hot air tray dryer (CIAE, India). The fresh pasta samples were kept in trays inside the dryer at 50°C for 2 hours to reduce the moisture content from 30-33% wb to 10-12% wb. The dried pasta products were packed and sealed for further analysis. Three replications were done for various ratios.

Table 1 shows the different levels of independent and dependent parameters studied in the present investigation. The prepared samples were coded as S1, S2, S3, and S4 as given in the Table 1. The market sample was coded as S5.

The dried pasta was analyzed for different properties such as .physical, colour, cooking, textural and sensory.

2.2. Physical Properties

The physical properties measured for pasta in the present study were specific length, sectional expansion ratio and bulk density.

2.2.1. Specific Length (SL)

Specific length (*SL*) was measured as per a standard method prescribed by Alvarez-Martinez et al. (1988) with slight modifications.

Random sample of 10 fresh pasta extrudates were selected and its length and weight were recorded. The length was measured using a digital vernier caliper (Mitutoyo, Japan) for the straight sample and thread was used for the curved one. The sample weight was measured using a digital balance (Shimatzu, Japan) with accuracy ±0.01g. The length of each extrudate sample was taken twice and average values were noted down. Specific length was calculated by the following expression (Eq. 1).

$$SL = \frac{L}{W} \quad \text{..... (1)}$$

Where, *SL* (mm) is the specific length, *L* (mm) is the length of extruded sample and *W* (g) is the weight of the extruded sample.

2.2.2. Sectional Expansion Index (SEI)

Sectional expansion index (*SEI*) was measured as per a standard method described by Alvarez-Martinez et al., (1988). 10 random fresh pasta samples were selected and their diameter was measured using a digital vernier calliper. Diameter of each extrudate was measured twice and average diameter values were found out to calculate *SEI*. *SEI* was calculated using the following equation (Eq. 2).

$$SEI = \frac{Ds}{Di} \quad \text{.....(2)}$$

Where *SEI* is sectional expansion index, *Ds* (mm) is diameter of the specimen and *Di* (mm) is diameter of the die.

2.2.3. Bulk Density

Bulk density of individual cylindrical pasta extrudates was estimated as the ratio of mass to volume for each sample including the control market sample. Weight of the samples was taken as 50 g using a digital balance, while a 250 ml measuring cylinder (Borosil) was used

to measure the volume of each sample. The cylinder was tapped 20 times for uniform compaction. The number of replications was three and average bulk density values were expressed as kg/m^3.

2.3. Colour

The colour of dried uncooked pasta samples were measured using a colorimeter (Hunter Lab Color Flex, U.S.A). The colorimeter was standardized with a black and white standard plate prior to analysis. The colour difference of the samples were recorded in terms of X, Y, Z, L*(lightness), a*(redness- greenness), and b*(yellowness-blueness) values. Three different readings were taken by rotating the sample in three different directions. Average of the three readings was recorded. Following the procedure given by Zardetto and Dalla Rosa (2009), the colorimetric difference (E*) for each sample was measured to obtain a better correlation between the visual and colorimetric differences using the following relationship (Eq. 3).

$$\sqrt{E^* = ((L^*)^2 + (a^*)^2 + (b^*)^2)} \quad \text{.....(3)}$$

Where, $L^* = L_0 - L$, $a = a_0 - a$, $b = b_0 - b$

L_0, a_0, b_0 are lightness, redness, yellowness value of market sample.

2.4. Cooking Properties

The cooking quality of the pasta samples were expressed in terms of water absorption ratio and dry matter loss. These parameters were determined as per the procedure reported by Zardetto and Dalla Rosa (2009) and Marti et al. (2010).

2.4.1. Water Absorption Ratio

30 g of dried pasta was cooked in a cooking pan for 4 minutes in an approximate ratio of 1:10 pasta/water taking 500 ml of tap water. The cooking water temperature was maintained at 98-100°C. The cooking period began as soon as the samples were put into the boiled water and were cooked for 4 minutes. The whole pasta sample was removed and drained. The weight of cooked pasta was measured after 5 minutes and water absorption ratio (*WAR*) was calculated by following expression (Eq. 4)

$$WAR = \frac{W_f}{W_b} \quad \text{.....(4)}$$

Where, *WAR* (g/g) is the water absorption ratio, W_f (g) is the weight of cooked sample and W_b (g) is the weight of uncooked sample.

2.4.2. Dry Mater Loss / Cooking Loss

After cooking, the level of gruel was brought back to initial volume i.e. 500 ml. Cooking loss was determined by evaporating the cooking water in a hot air oven at 105°C to constant weight taking 25 ml of cooking water. Dry matter loss (*DL*) during cooking was calculated as (Eq. 5).

$$DL = \frac{DM}{Wd} \quad \text{...... (5)}$$

Where *DL* (%) is dry matter loss, *DM* (g) is dry matter and W_d (g) is dry weight of uncooked pasta.

2.5. Textural Analysis of Cooked Pasta

The textural qualities of the cooked pasta in terms of firmness was measured using a TA – HD plus Texture Analyser (Stable Micro System Ltd., England) calibrated for a load cell of 500000 g using a Kramer shear cell with five blades. The measurement conditions were: test speed 2.00 mm/s, post-test speed 10.00 mm/s, distance 50mm and data acquisition rate of 200pps. The force-time plot of all samples including the control market sample was obtained. These force-time plots peak at a particular point and followed by a steep fall in the force axis, which shows that the resistance ceases to exist. These plots were used to calculate firmness of the pasta samples.

3. Results and Discussion

3.1. Analysis of Raw Material

Four prepared pasta samples and one market sample were analyzed in the present study. The average moisture content of wheat flour and millet flour prior to cold extrusion were 7.63±0.02% and 5.67±0.03% wet basis (wb) respectively. The average moisture content of pasta just after extrusion and dried pasta were found out to be 31.73±1.01 % wb and 11.84 ± 1.01 % wb respectively. The moisture content of the market sample was found to be 12.23 % wb.

3.2. Physical Properties of Dried Fortified Pasta

3.2.1. Specific Length and Sectional Expansion Index

The specific length (*SL*) and sectional expansion index (*SEI*) for the developed products were measured and the average values of three replications for the developed products are listed in Table 2. Since, specific length and sectional expansion ratio are dependent on the machine die dimensions, only one average SL and SEI is reported for all the samples. From Table 2, average specific length of the developed products was found to be 27.70 ± 0.99 mm and average sectional expansion ratio was 0.91 ± 0.006. The average specific length of market product was found to be 39.77±3.7 mm. Since the die dimensions for the market product was not available, SEI could not be calculated for this sample (S5).

3.2.2. Bulk Density

Bulk density (BD) values of the extruded pasta products varied between 281.71±3.42 and 301.88±16.17 $kg.m^{-3}$ for different samples. The bulk density of the market pasta sample was estimated to be 349.66 $kg.m^{-3}$. Fig. 1 (a) depicts the variation in the measured values of bulk density for the developed pasta samples with different ratios of wheat to millet flour. Error bars are also included in the Fig. 1 (a) to show the variations of replications from the average value.

From Fig.1 (b), it can be observed that average bulk density of the developed pasta and millet proportion are negatively correlated with correlation coefficient of 0.987 and R^2 value of 0.976 thus as the amount of millet flour increases in the pasta samples, the bulk density of the extruded product decreases. This may be attributed to the lower bulk density value of millet flour than wheat flour.

3.2.3. Colour of Fortified Pasta

The colour parameters of the uncooked pasta samples were estimated using a colorimeter (Hunter Lab Color Flex, U.S.A). The L*, a*, b* and ΔE* values of the developed pasta samples are presented in Table 3.

The highest L* value (brightness) was found for S5 followed by sample S1 which can be explained due to absence of millet flour. Highest a* value (redness) was observed with the S1 and lowest value for the market sample (S5). The b* value (yellowness) was highest with the market sample and lowest for S4 which content highest amount of millet flour. High value of b* is especially desirable for pasta colour. Yellowness of market sample is high because of presence of other ingredients, especially egg which gives good colour to pasta. However, due to brown colour of millet flour yellowness of millet fortified pasta samples was masked. Thus a decreasing trend in b* values was observed with increase in millet flour content. The total colorimetric difference (ΔE*) with respect to market sample was found highest in S3 sample which may be due to high percentage of millet flour and S1 had the lowest value.

3.2.4. Cooking Quality

The cooking quality of pasta is one of the most important features that encompass the following characteristics: a) the uncooked to cooked weight ratio indicating the water uptake (hydration) during cooking; and b) the cooking loss, related to solid leaching during cooking and considered as an indicator of the overall cooking.

3.2.4.1. Water Absorption Ratio (WAR)

A required factor in determining pasta products is having good water absorption. Hummel (1966) reported that good quality macaroni products should absorb at least twice their weight after boiling in water. Similar results were obtained in the present study where weight of uncooked pasta samples increased almost twice after boiling. Average water absorption ratios for the developed products were calculated using Eq. (4) and results are shown in Table 4. Highest value (1.16±0.09) of water absorption ratio was found for S4 sample with 2:1 ratio and lowest value of (0.81±0.07) was obtained for S1 (1:0). Fig. 2 depicts the effect of millet flour addition on water absorption ratio for developed products. As observed from Fig 2, there is increase in water absorption ratio with increase in millet flour content in pasta samples with correlation coefficient of 0.971 and R^2 value of 0.945. This may be due to high percentage of millet flour in S4. Since millet flour contains non-gluten proteins and more starch it may have resulted in high hydration of starch leading to increase in weight of cooked pasta. Similar type of behaviour was observed by Petitot et al. (2010) for legume flour based pasta. Water absorption ratio for the market sample was found out to be 0.99. The water absorption ratio of market sample could not be compared with the developed products due to difference in ingredients used.

3.2.4.2. Dry Matter Loss / Cooking Loss

Dry matter loss was for the developed pasta samples were estimated using the Eq. (5). Cooking loss was found highest (0.38±0.15 %) for S1 (1:0) and lowest value of 0.11 was observed for market sample (S5). Fig. 2 shows the effect of millet flour fortification on cooking loss for various samples investigated in the present study and it is found out that millet proportion and dry matter loss are slightly negatively correlated with correlation coefficient of 0.565 and R^2 value of 0.319. Thus a slight decrease in cooking loss was observed with increase in millet flour content. This may be attributed to non-gluten proteins and insoluble fibers present in millet flour which weakened the overall structure of pasta resulting in higher cooking loss. Similar type of trend for cooking loss was reported by Petitot et al. (2010) for legume flour based pasta and Torres et al. (2007) for pigeon pea flour based pasta.

3.2.5. Textural Analysis of Cooked Pasta

Firmness of cooked pasta was expressed as the force required to bite through the product between the molar teeth (Oh et al, 1983). The force-time graph obtained from texture analysis for all five samples is shown in Fig.3. As evident from Fig. 3 (a), the force-time plots peak at a particular point followed by a steep fall over in the force axis, which shows that the resistance ceases to exist. The force corresponding to the peak point was taken as the firmness value for the samples.From Fig. 3 (a), highest firmness (205.73N) was observed for sample with ratio 4:1 (S3) followed by samples with 2:1 (S4), 8:1(S2), 1:0 (S1). The lowest value (147.87N) was observed for the market sample (S5). From Fig 3 (b), it is found that millet proportion and firmness of developed pasta are slightly positively correlated with a correlation coefficient of 0.653 and R^2 value of 0.426. Similar reasoning of weakened overall structure of pasta due to non-gluten proteins and insoluble fibers of millet flours may be considered for the above firmness behaviour in pasta samples.

4. Conclusion

Millet fortified pasta offer a broader spectrum for people wishing to improve the nutritional quality of their diet (enrichment in proteins and fibres, vitamins, minerals complementarily). However, substitution of durum wheat semolina with different levels of millet flour required an adaptation of the pasta making process at a pilot-scale. Indeed, higher mixing speed and lower hydration level were required during mixing (particularly when processing durum wheat semolina with millet flour) and thus facilitate the extrusion of the dough to limit the agglomeration of particles. From the present study, it is found that the bulk density of the extruded product decreases as the amount of millet flour increases in the pasta samples. Moreover, the fortification of pasta with millet flour had a noticeable impact on the cooking quality of pasta. An increase in water absorption ratio and slightly decrease in cooking loss with increase in millet flour content in pasta samples was observed. A slight decrease in firmness of pasta samples was observed with decrease in millet flour content. Detail studies of textural properties and nutritional content of the millet fortified pasta need to be carried out to enhance the chewiness and nutritional value of the cooked pasta products. Further investigation should be focused on the optimisation of proportions of wheat flour to millet flour based on pasta quality attributes.

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Annexure

Independent Variable	Levels of Independent Variable		Dependent Variables		
Ratio of wheat flour to millet flour	1:0	(S1)	Moisture properties,	content, colour,	physical cooking
	8:1	(S2)			
			properties,	textural properties and	
	4:1 (S3)		sensory evaluation		
	2:1 (S4)				
	Market (S5)				

Table 1: Experimental variables for pasta production

Ratio of WF to MF	SL, mm	Average SL, mm	SEI	Average SEI
1:0	26.67	27.70 ±0.99	0.91	0.91±0.006
2:1	28.79		0.91	
4:1	28.24		0.91	
8:1	27.09		0.92	
Market	39.77± 3.7		-	

Table 2: Specific length and expansion ratio of developed extruded products

Samples	L*	a*	b*	ΔE*
Market (S5)	60.86±0.59	3.28±0.93	28.16±1.24	Reference
1:0 (S1)	46.11±0.83	8.20±0.39	21.39±3.17	17.21±2.58
8:1 (S2)	42.71±0.81	7.29±0.79	15.11±0.41	22.77±0.47
4:1 (S3)	38.56±1.79	7.62±0.13	12.47±0.58	27.47±2.78
2:1 (S4)	39.33±0.84	6.71±0.03	11.74±0.16	27.32±0.33

Table 3: Colour parameters of uncooked pasta samples

Samples	Average WAR(g/g)	Average DL (%)
Market (S5)	0.99	0.11
1:0 (S1)	0.81±0.07	0.38±0.15
8:1 (S2)	0.90±0.06	0.34±0.05
4:1 (S3)	1.06±0.24	0.27±0.09
2:1 (S4)	1.16±0.09	0.32±0.14

Table 4: Average water adsorption ratio (WAR) and dry matter loss (DL)

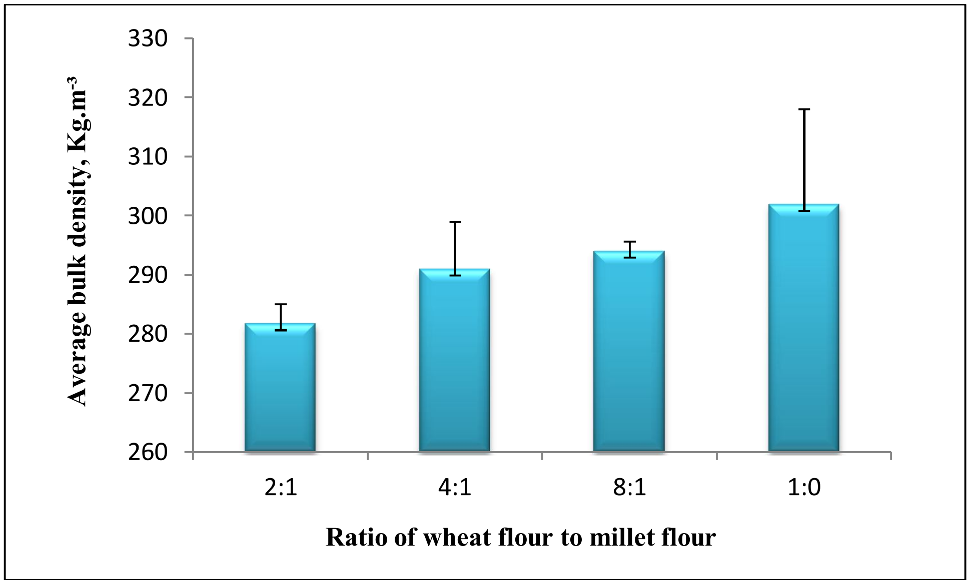

Figure 1: Variation in bulk density for developed pasta products

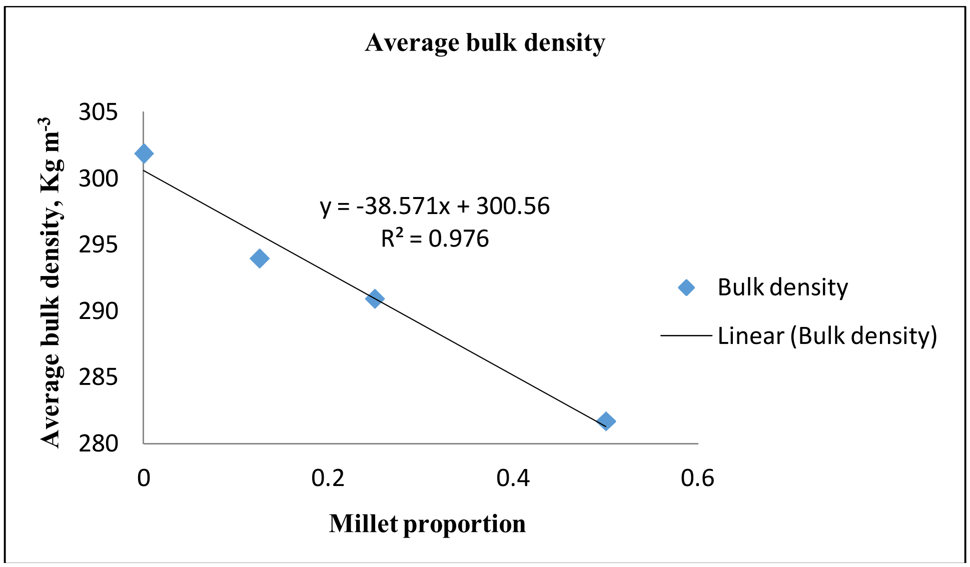

Figure 2: Relation between average bulk density and millet proportion for developed pasta products

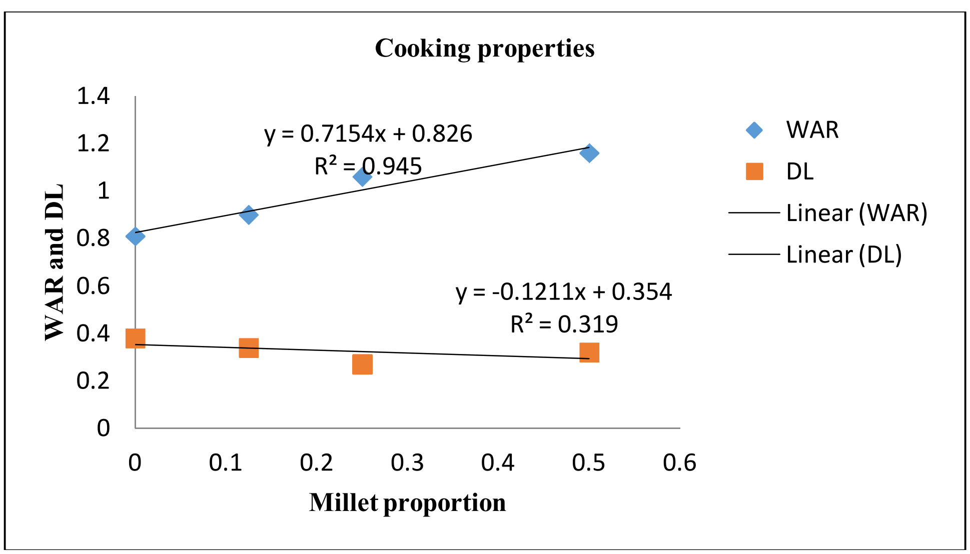

Figure 3: Water absorption ratio (WAR) and dry matter loss (DL) of developed pasta products

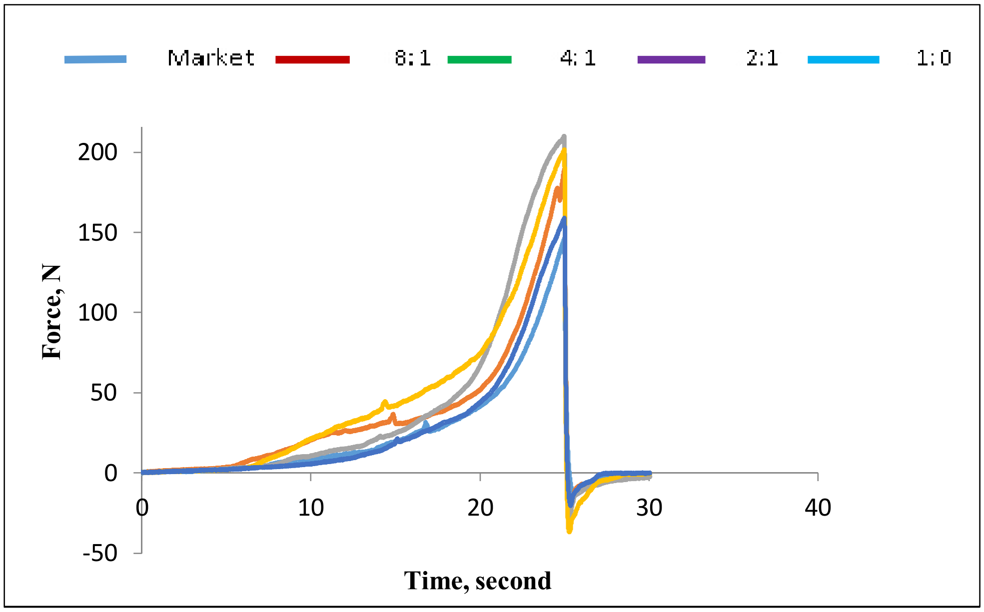

Figure 4: Force-time plots of pasta samples

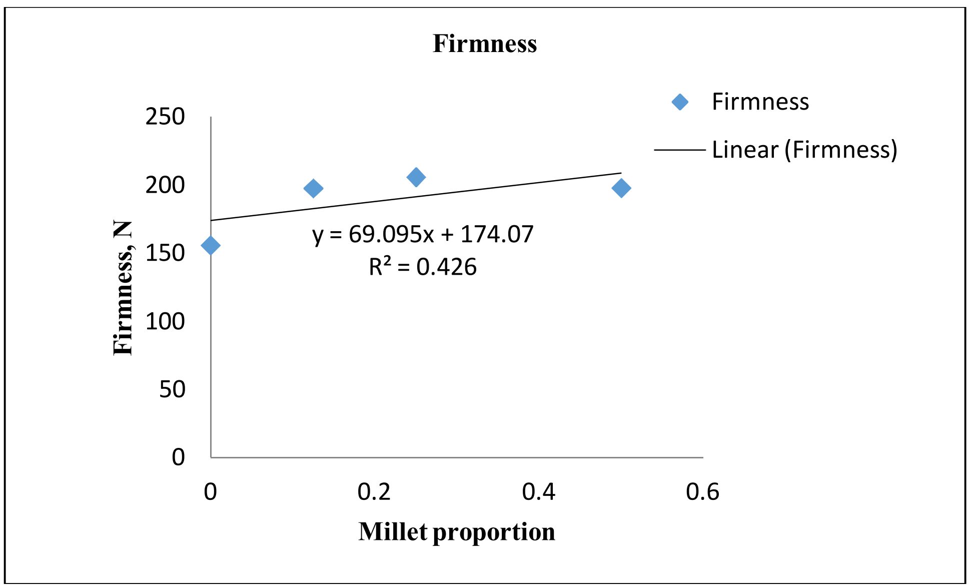

Figure 5: Relationship between pasta firmness and millet proportion