International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 979-984

Received: 15-09-2018
Accepted: 20-10-2018

Kirti Jalgaonkar
Division of Horticultural Crop Processing, ICAR-CIPHET, Abohar, Punjab, India

SK Jha
Division of Food Science and Postharvest Technology, ICAR-IARI, New Delhi, India

Manoj Kumar Mahawar
Division of Horticultural Crop Processing, ICAR-CIPHET, Abohar, Punjab, India

Correspondence
Kirti Jalgaonkar
Division of Horticultural Crop Processing, ICAR-CIPHET, Abohar, Punjab, India

Influence of die size and drying temperature on quality of pearl millet based pasta

Kirti Jalgaonkar, SK Jha and Manoj Kumar Mahawar

Abstract
An innovative approach is proposed to study the influence of die size and drying temperature on the quality characteristics of pasta made from blend of wheat semolina and pearl millet flour in the ratio of 50:50 having particle size of 425 µm. Initially, pasta of wall thickness 0.49, 0.91 and 1.33 mm was prepared and submitted to cooking time, cooking loss and textural properties. Observation indicated that pasta with wall thickness of 1.33 mm had poor cooking stability, texture and surface stickiness property than 0.91 mm and 0.49 mm thickness pasta. Pasta of 0.91 mm thickness had least cooking loss, cooking time and good textural properties. Further, quality of pasta dried at different drying temperature (50, 60, 70, 80, 90°C) was studied in terms of colour, cooking loss and hardness. L values (lightness) ranged from 39.89 to 31.13, decreasing (becoming darker) with increased drying temperature. Hardness for cooked pasta ranged from 10.58 to 13.06 N, with higher values for pasta dried at 90°C. Cooking loss ranged from 9.17 to 8.48 %. However, drying temperature showed non- significant (*$p>0.05$*) effect on cooking loss. Results pointed out that pasta dried at 50°C was lighter in colour, good texture and minimum cooking loss than the pasta dried at higher temperatures.

Keywords: pasta, pearl millet flour, die size, drying temperature

Introduction
The principal raw material for preparing pasta of premium quality is 100% durum wheat semolina. Recently, the production of dried pasta from a mixture of semolina and other flours such as wheat flour, whole wheat flour, bran-semolina, corn, rice, oat, legumes, millet flour and so on, is progressively increasing. The main reason for such replacement are, lower availability of semolina in some parts of the world, production of unique kind of pasta with other flours, the elimination of gluten for special diet products, and the increase of nutritional benefits of enriched pasta (Marti *et al*., 2014) [22]. Therefore in the present study, non-traditional raw material such as pearl millet (*Pennisetum glaucum*), gluten free grain, was used for preparation of pasta. Pearl millet is a course cereal grain with high levels of calcium, iron, zinc, lipids, and proteins (Jalgaonkar and Jha, 2016) [16]. Pearl millet flour has short shelf life of 5 to 10 days (Jalgaonkar *et al*., 2016; Tiwari *et al*., 2014) [17, 28]. Also, it is quite difficult to produce pasta from 100% pearl millet flour as these disintegrated after cooking. Hence, blend composition (wheat semolina: pearl millet flour) in the ratio of 50:50 could be used to make pasta with acceptable quality (Jalgaonkar and Jha, 2016) [16]. The prepared pasta could be safely stored in biaxially oriented polypropylene packaging material for 6 months at ambient condition without undue effect on its quality characteristics (cooking quality, textural quality, sensory quality, microbial load) (Jalgaonkar *et al*., 2017) [15].

The utilization of such non-traditional ingredients for pasta making necessitates the optimization of process parameters, most importantly the drying temperature. During drying, moisture content of product is reduced to around 12.5% in order to allow a long shelf life, translucent appearance and retention of shape. When drying is slow, pasta products tend to spoil or become moldy, but when the drying is rapid, moisture gradients occur resulting in harder surface that cause the products to crack or check, resulting in weak structure which may rise to breakage of the product during packaging and handling, negatively affecting pasta quality (Feillet and Dexter, 1996) [11]. Better results could be obtained by application of low temperature drying (<55°C) to reduce the moisture content of pasta, followed by a high temperature drying (>60°C). Increasing drying temperature at the moisture below 16-18%, resulted in good quality pasta (Resmini and Pagani, 1983) [27].

High temperature drying may lead to excessive swelling of starch granules with the consequent rupture of protein network and the deterioration of cooking quality of pasta (Resmini *et al*., 1988) [26]. D' Egidio *et al*. (1990) [9] pointed out some benefits of high temperature drying (>60°C) of pasta viz. reduced cooking loss, decreased surface stickiness, higher firmness and tolerance to over-cooking. However, application of higher drying temperature promoted the occurrence of Maillard reaction, leading to unacceptable brownish colour and lowering of the availability of lysine content in pasta (Petitot *et al*., 2010) [24].

The prime role of die holes is to provide desired shape and size to pasta (Pollini *et al*., 2012) [25]. Pasta dimensions, extrusion pressure and the surface condition get affected by the type and condition of die (Maldari and Maldari, 1993) [19] and hence affect the product quality. Pasta made from pearl millet is a growing market but little information is available on optimal drying conditions. In the present work, a novel approach to evaluate the effect of die size as well as drying temperature on cooking and textural quality of pearl millet based pasta has been described.

Materials and Methods

Pasta preparation

Pasta was prepared using a mixture of wheat semolina (WS) and pearl millet flour (PMF) in the ratio of 50:50 having particle of 425 µm (Jalgaonkar and Jha, 2016) [17] were processed in twin screw extruder (BTPL make, Kolkata, India) under the following operating conditions: feed moisture content 30% w.b.; barrel temperature 70°C; feeder speed 12 rpm; screw speed:feeder speed 10 (Jalgaonkar *et al*., 2018) [14].

Die determines the shape of the product and the pressure inside the barrel and affects the product quality. Hence, suitability of the die was studied initially. The cylindrical hollow shape of pasta was made with a special die where a pin was suspended in the die hole from the back side. Dough, which was forced through the die, flowed around the supports of the pin and then recombined in the annulus between the central pin and the die chamber so that a smooth, round and hollow tube emerged from the die. Three different pins of diameter 6.72 mm, 5.88 mm and 5.04 mm were fitted in the die hole of diameter 7.69 mm. Thus, the pasta obtained through this die assembly had hollow cylindrical shape with different wall thickness of 0.49 mm, 0.91 mm and 1.33 mm. Quality parameters and post-cooking stability of pasta were determined to ascertain the suitability of the die.

Since pasta obtained after extrusion had high moisture content, drying was essential. Therefore, drying temperature appropriate for this purpose was standardized. Drying of pasta was carried out in tray dryer (MSW-216, Macro Scientific Works, New Delhi) using five different drying conditions (50, 60, 70, 80, and 90°C). The drying was continued till the pasta achieved 8-9% moisture content. Suitability of the temperature was determined through the quality parameters of the pasta.

Quality evaluation of pasta

Chemical analysis

Moisture (Method 925.10), protein (Method 960.52), ash (Method 923.03) and fat content (ether extract, Method 920.85) of wheat semolina and pearl millet flour was determined using Association of Official Analytical Chemists (AOAC, 1990) [5]. Carbohydrate was calculated by subtracting the sum of moisture, protein, ash and fat from 100 (Merrill and Watt, 1973) [23]. The iron and zinc contents of the samples were estimated using the respective standard curve prepared for each element (AACC, 2003 Method 40-70) [1] and absorbance was read in atomic absorption spectrophotometer (ZEEnit-700, USA).

Cooking time

Cooking time is the minimum time necessary for starch gelatinization. It was assessed by pressing cooked pasta between two glass plates and measuring the time for the white core to disappear (Abecassis *et al.*, 1994) [2].

Cooking loss

BIS method [BIS: 1485-(2010)] [7] was used to determine the cooking loss. Ten grams of pasta were cooked in 200 ml of boiling water stirring. After cooking, the sample was rinsed with a stream of water (around 50 ml) for about 30 s in a funnel. Water was allowed to drain for 2 min. The total volume of gruel and the rinsed water collected was measured. 20 ml of the gruel was pipette out after stirring to give even distribution of solid content into a tarred petri dish. The petri dish was then transferred to hot air oven maintained at 105°C and sample was dried to constant mass. It was calculated using Eq. 1.

$$Cooking\ loss\ (\%) = \frac{(M1 - M) \times V\ \times 100}{20\ \times Weight\ of\ uncooked\ pasta} \quad (1)$$

Where, M 1= mass in grams of petri dish with total dry solids, M = mass in grams of empty petri dish, V= total volume of gruel in ml

Hardness and chewiness

A texture profile analysis (TPA) of pasta was conducted to determine hardness and chewiness of cooked pasta using Texture Analyser (Model: *TA+HDi*®, Stable Micro Systems, UK) using settings *viz.* pre-test speed: 3 mm/s; test speed: 1 mm/s; post-test speed: 10 mm/s; distance: 50% in compression mode; time: 1 s; data acquisition rate: 200 pps with cylindrical probe (p/75 mm). From the TPA curve as shown in Fig. 1, hardness and chewiness of cooked pasta were calculated as suggested by Limroongreungrat and Huang (2007) [18].

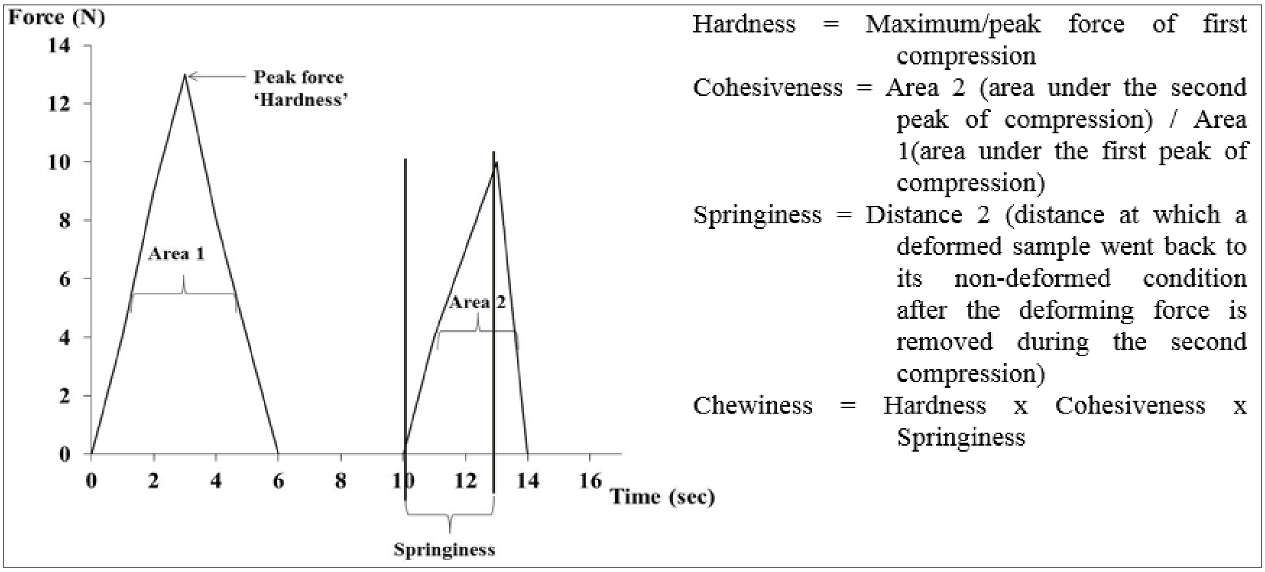

Fig 1: Texture profile analysis (TPA) curve.

Colour
Colour was measured using Hunter colour lab (Model: LX16244, Hunter associates Laboratory, Virginia). Dry pasta samples (10-12g) were placed in the sample cup covered with lid for measurement. Colour values were recorded as 'L*' (lightness), 'a*' (redness and greenness) and 'b*' (yellowness and blueness).

Statistical analysis
The general linear models (GLM) procedure was used for data analysis by taking ten replications for all the experiments. Where significant differences were found, means were separated using the least significant difference using Statistical Analysis Software (SAS) version 9.3. Significance was accepted at $p<0.05$.

Results and Discussion
Proximate composition of wheat semolina and pearl millet flour
The proximate composition of WS and PMF of particle size 425 µm used for preparation of pasta is shown in Table 1. The protein, ash, fat, iron and zinc content were found to be higher in PMF than WS, while WS contained higher carbohydrate content than that of PMF.

Table 1: Proximate composition of PMF and WS of particle size 425 µm

S. No.	Composition	WS	PMF
1.	Moisture content (% w.b.)	10.49±0.02	10.48±0.05
2.	Protein (%)	10.06±0.05	11.90±0.01
3.	Ash (%)	0.47±0.01	1.16±0.02
4.	Fat (%)	0.99±0.03	4.28±0.03
5.	Carbohydrates (%)	77.99±0.02	72.18±0.03
6.	Iron (mg/100g)	0.98±0.02	8.92±0.02
7.	Zinc (mg/100g)	0.12±0.02	2.89±0.01

Notes: Values are mean ±SE of ten replications

Effect of die size on pasta quality and stability
Cooking time (CT) and Cooking loss (CL)
Variation in the die size changed the thickness of pasta. The wall thickness had significant ($p<0.05$) effect on CL and CT (Table 2). It was also observed that pasta with smaller thickness required less time to cook and vice versa. Table 2 showed that it takes 5.93 min for cooking of 0.49 mm wall thickness of pasta followed by 8.01 min for 0.91 mm and 16.69 min for1.33 mm, respectively.

However, non-significant difference ($p>0.05$) in CL and CT was found between pasta made of 0.49 mm and 0.91 mm thickness (Table 2). Pasta of 0.49 and 0.91 mm thickness had CL ≤ 8% as suggested for products like macaroni, spaghetti, vermicelli and egg noodles by the Indian Standard (BIS:1485 2010) [7]. However, CL in pasta of thickness 1.33 mm exceeded that critical limit, which could be due to the increase in the die opening area and wall thickness of pasta that further resulted in lowering of friction/shear stress in the extruder. Thus, lesser pressure drop on the die creates faster flow of material which develops improper texture to product after drying and ultimately enhances the loss of solids during cooking. Similarly, Abecassis *et al*. (1994) [2] reported that increase in the open surface of die affect the surface condition, viscoelasticity of dough and decrease the die pressure.

Table 2: Effect of die size on cooking time, cooking loss, hardness and chewiness of cooked pasta

Pasta thickness (mm)	Cooking time (min)	Cooking loss (%)	Hardness (N)	Chewiness (N.mm)
0.49	5.93±0.35^{b}	7.23±0.10^{b}	10.94±0.05^{a}	6.11±0.02^{a}
0.91	8.01±0.03^{b}	8.01±0.03^{b}	9.80±0.29^{a}	5.78±0.48^{a}
1.33	16.69±0.19^{a}	10.01±0.01^{a}	5.93±0.19^{b}	3.55±0.23^{b}
F value	427.26^{S}	311.06^{S}	87.00^{S}	47.32^{S}

Error d.f.	18	18	18	18
Error MS	0.228	0.020	0.234	0.123
LSD	1.08	0.32	1.10	0.79

(Values are mean ± SE of three replications; mean in the same columns followed by same superscript letter are not differed significantly at *p<0.05*; d.f. refers to degrees of freedom; MS refers to mean sum of square; LSD refers to least significance difference; [S]Significant at 5%)

Hardness and chewiness

Good quality pasta is characterized by higher firmness and chewiness. Hardness and chewiness of pasta decreased from 10.94 to 5.93 N and from 6.11 to 3.55 N mm, respectively with increase in the thickness from 0.49 to 1.33 mm. Maximum hardness (10.94 N) and chewiness (6.11 N.mm) was observed for pasta with 0.49 mm thickness. It was observed that thickness significantly (*p<0.05*) affected hardness and chewiness (Table 2). However, the difference between 0.49 and 0.91 mm pasta was non-significant (Table 2). With increase in the gap between the inserted pin and die chamber, less pressure was created on the die which makes the smooth material flow resulted in decreased barrel temperature inside the extruder. With decrease in the barrel temperature, decrease in the degree of starch gelatinization was observed. Therefore, more leaching of solids took place during cooking which deteriorate the surface characteristics of pasta.

Pasta stability

Physical observations on post-cooking of pasta showed that pasta with wall thickness of 1.33 mm had poor cooking stability, texture and surface stickiness property (Fig. 2) than 0.91 mm and 0.49 mm thickness pasta. Thus, die size corresponding to preparation of pasta of 0.91 mm thickness was selected on the basis of cooking loss (<8%) and good textural properties for further studies.

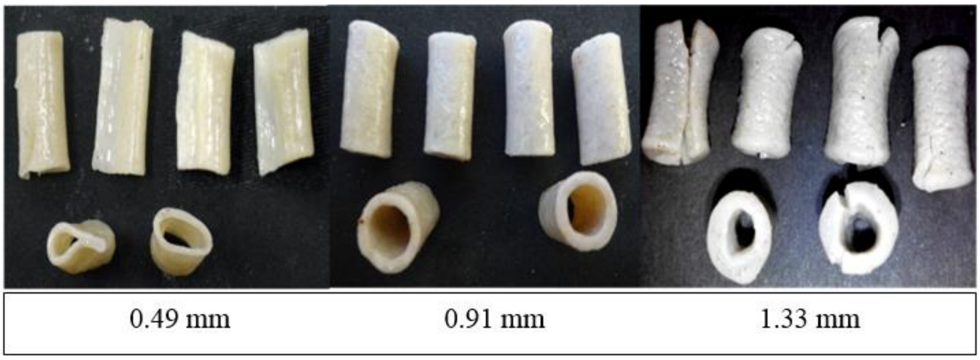

Fig 2: Pasta prepared with different wall thickness

Influence of drying temperature on quality of pasta

Pasta obtained after extrusion has high moisture content and hence drying to appropriate moisture content was necessary before storage. Choosing an appropriate temperature for drying of pasta is an important step which determines the final product quality. Pasta dried at 50, 60, 70, 80 and 90°C required 2, 1.67, 1.33, 1.00 and 0.83 h, respectively of drying time to reach the desired moisture content (8-9% w.b).

Colour

Colour of dry pasta was significantly (*p<0.05*) affected by drying temperature. An increase in drying temperature from 50 to 90°C resulted in deterioration of pasta colour. Table 3 shows that L* (lightness) and b* value (yellowness) of pasta decreased from 39.89 to 31.13 and 17.21 to 14.44, respectively, whereas a* value (redness) increased from 0.71 to 2.50 with increase in the drying temperature from 50-90°C. Pasta dried at low temperature (50°C) was brighter than dried at higher temperature (90°C).

Similarly, Ansari *et al*. (2013) [4] reported that L* value of 20% defatted soy fortified spaghetti dried at 70°C (51.86) was lower than 52°C (52.27) which might be due to the exposure of higher heat to the product while drying. Also, occurrence of non-enzymatic browning resulted in reduction of lightness in spaghetti (Acquistucci, 2000; Garcia-Banos *et al.*, 2004) [3]. Howard *et al*. (2011) [13] highlighted that L value (58.52) for peanut flour supplemented pasta dried at 88°C was significantly lower that the pasta dried at 60 or 74° (61.7 and 61.9, respectively).

High temperature drying of durum wheat spaghetti at low feed moisture content enhanced the browning of pasta (Zweifel *et al.*, 2003) [29]. Howard also pointed out that pasta became dark in colour as drying temperature increased from 60 to 88°C. Similarly, brightness of spaghetti made from semolina and semolina added with buckwheat bran flour (10-30%) dried at higher temperature (90°C) was less than dried at lower temperature (40°C) (Manthey *et al*., 2004) [21].

Table 3: Influence of drying temperature on L*, a* and b* value of dry pasta

Drying temperature (°C)	L*	a*	b*
50	39.89±0.16^a	0.71±0.02^d	17.21±0.10^a
60	38.55±0.04^a	1.72±0.01^c	16.87±0.01^a
70	35.39±0.12^b	1.78±0.06^c	15.60±0.04^b
80	34.07±0.35^b	2.05±0.01^b	15.29±0.02^b
90	31.13±0.44^c	2.50±0.03^a	14.44±0.15^c
F value	121.85^S	264.32^S	46.55^S
Error d.f.	36	36	36
Error MS	0.303	0.005	0.029
LSD	1.04	0.13	0.32

(Values are mean ± SE of three replications; mean in the same columns followed by same superscript letter are not differed significantly at *p<0.05*; d.f. refers to degrees of freedom; MS refers to mean sum of square; LSD refers to least significance difference; [S]Significant at 5%)

Cooking loss

Cooking loss of pasta varied from 8.48 to 9.17% with variation in drying temperature from 50 to 90°C (Fig. 3).

High CL (9.17%) was observed in pasta dried at 50°C whereas corresponding lower value (8.48%) was observed for pasta dried at 90°C. The reduction of CL with increase in temperature may be due to formation of partial coagulation of gluten structure during high temperature drying leading to minimum loss of starch (Braibanti, 1980) [8]. Similarly, Fang and Khan (1996) [10] found out that increase in drying temperature from 40 to 90°C decreased the CL of elbow macaroni prepared from durum wheat semolina from 6.7 to 5.9 %. Manthey and Schorno (2002) [20] highlighted that cooking loss was greater for spaghetti dried at 40°C (6.5%) than at 70°C (5.8%).

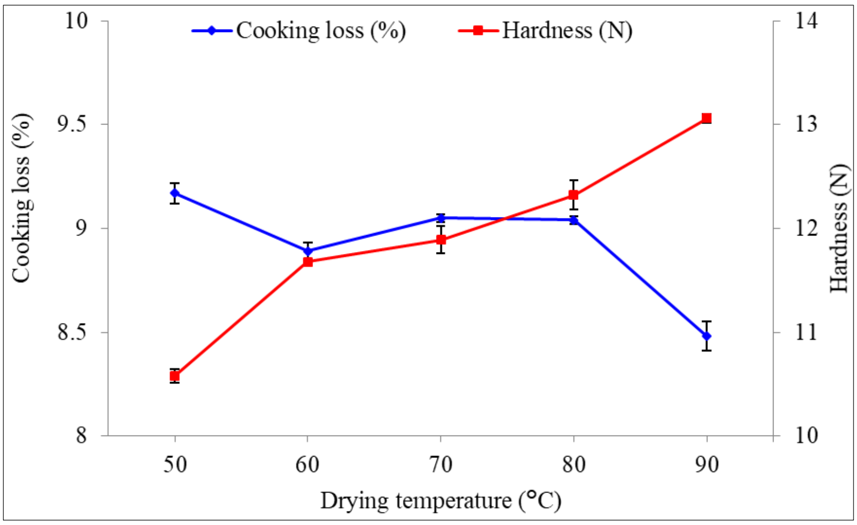

Fig 3: Effect of drying temperature on cooking loss and hardness of cooked pasta

However, from the statistical point of view, this decrease in CL was non-significant (Table 4). Howard *et al*. (2011) [13] too reported that an increase in temperature from 60 to 88°C resulted in non-significant effect on cooking loss (6.67 to 6.58%) of wheat flour based pasta supplemented with peanut flour (30-50%) and carrageenan (2.4-2.9%).

Table 4: ANOVA for cooking loss and hardness of pasta affected by drying temperature

Drying temperature (°C)	Cooking loss (%)	Hardness (N)
F value	1.91^{NS}	736.35^{S}
Error df	36	36
Error MS	0.113	0.005
LSD	0.63	0.13

Notes: d.f. refers to degrees of freedom; MS refers to mean sum of square; LSD refers to least significance difference; ^{S}Significant; ^{NS}Non-significant at 5%

Hardness

With the increase in drying temperature, hardness of cooked pasta increased from 10.58 to 13.06 N (Fig. 3). Hardness was found lower (10.58 N) in pasta dried at 50°C whereas corresponding high values (13.06 N) was observed for pasta dried at 90°C. Results suggested that the difference between hardness was small, but the end product firmness was greater when pasta dried at higher temperature rather than dried at lower temperature. High drying temperature strengthens the gluten matrix which provides protection for starch granules for rupturing during cooking (Manthey and Schorno, 2002) [20] which improved the texture of pasta.

Howard *et al*. (2011) [13] reported that pasta dried at 88°C was significantly firmer (2.13 N) than pasta dried at 60°C (1.55 N). Zweifel *et al*. (2013) [29] observed that increase in drying temperature from 80 to 100°C increase the firmness of durum wheat pasta. Wheat flour pasta supplemented with 20% defatted soy flour showed lower firmness (1.85 N) at 52°C of drying temperature than drying at 72°C temperature (2.09 N) (Ansari *et al*., 2013) [4]. Manthey *et al*. (2004) [21] reported that pasta prepared from semolina and semolina added with buckwheat bran flour (10-30%) dried at higher temperature (90°C) had highest firmness than dried at lower temperature (40°C).

It was inferred from the study that pasta dried at 50°C was lighter in colour and softer in texture. Physical observation showed development of slight cracks in pasta which was dried at higher temperature 80-90°C, which reduced the pasta appearance. Hence, drying of pasta at 50°C for 2 h till moisture content reached to 8-10% was considered appropriate for development of pearl millet based pasta.

Conclusion

Overall results of this investigation indicated that die size significantly affected the pasta stability after cooking. In particular, pasta sample with wall thickness of 1.33 mm required more cooking time, high cooking loss with least hardness and chewiness compared to pasta of 0.49 and 0.91 mm wall thickness. Instead, there was non-significant difference in quality of pasta of 0.49 mm and 0.91 mm wall thickness. Results also suggested that increasing drying temperature for pearl millet based pasta resulted in decreased cooking loss, increased hardness and darker colour in dry pasta. Hence, pearl millet pasta of wall thickness 0.91 mm dried at 50°C for 2 h till moisture content reached to 8-10% was considered optimum.

Acknowledgements

Financial support in the form of INSPIRE fellowship from Department of Science and Technology, Government of India is duly acknowledged. Also, gratitude is extended to NAE project of ICAR for facilities received.

References

1. AACC. American Association of Cereal Chemists. Approved Methods of the AACC, tenth ed. (St. Paul, Minnesota, USA), 2003.
2. Abecassis J, Abbou R, Chaurand M, Morel MH, Vernoux P. Influence of extrusion conditions on extrusion speed,

temperature and pressure in the extruder and on pasta quality. Cereal Chemistry. 1994; 71(3):247-253.
3. Acquistucci R. Influence of Maillard reaction on protein modification and color development in pasta. Comparison of different drying conditions, LWT- Food Science and Technology. 2000; 33(1):48-52.
4. Ansari A, Kalbasi-Ashtari A, Gerami A. Effects of defatted soy flour, xanthan gum and processing temperature on quality criteria of spaghetti. Journal of Agriculture Science and Technology 2013; 15(2):265-278.
5. AOAC. Official method of analysis of the association of official analytical chemists, fifteen ed. (Washington, DC), 1990.
6. Baiano A, Conte A, Del Nobile MA. Influence of drying temperature on the spaghetti cooking quality. Journal of Food Engineering. 2013; 76(3):341-347.
7. BIS: 1485. Macaroni, Spaghetti, Vermicelli and Egg Noodles-specification, second revision Bureau of Indian Standards, New Delhi, 2010.
8. Braibanti CSPA. New developments in pasta drying technology. Macaroni Journal. 1980; 61(12):48-50.
9. D'Egidio MG, Mariani BM, Nardi S, Novaro P, Cubadda R. Chemical and technological variables and their relationships: A predictive equation for pasta cooking quality. Cereal Chemistry. 1990; 67(3):275-281.
10. Fang K, Khan K. Pasta containing regrinds: effect of high temperature drying on product quality. Cereal Chemistry. 1996; 73(3):317-322.
11. Feillet P, Dexter JE. Quality requirement of durum wheat for semolina milling and pasta production. In: Kruger, J. E., Matsuo, R. R., Dick, J. W. (Eds.), Pasta and Noodle Technology. AACC International, St. Paul, MN, USA, 1996, 95-131.
12. Garcia-Banos JL, Corzo N, Sanz ML, Olano A. Maltulose and furosine as indicators of quality pasta products. Journal of Food Chemistry. 2004; 88(1):35-38.
13. Howard BH, Hung Y, McWatters K. Analysis of ingredients functionality and formulation optimization of pasta supplemented with peanut flour. Journal of Food Science. 2011; 76(1):40-47.
14. Jalgaonkar K, Jha SK, Mahawar MK. Influence of incorporating defatted soy flour, carrot powder, mango peel powder and moringa leaves powder on quality characteristics of wheat semolina-pearl millet pasta. Journal of Food Processing and Preservation 2018; 42(4):e13575.
15. Jalgaonkar K, Jha SK, Nain L, Iquebal MS. Quality changes in pearl millet based pasta during storage in flexible packaging. Journal of Agricultural Engineering 2017; 54(3):22-31.
16. Jalgaonkar K, Jha SK, Sharma DK. Effect of thermal treatment on the storage life of pearl millet (*Pennisetum glaucum*) flour. Indian Journal of Agricultural Sciences 2016; 86(6):762-767.
17. Jalgaonkar K, Jha SK. Influence of particle size and blend composition on quality of wheat semolina-pearl millet pasta. Journal of Cereal Science. 2016; 71:239-245.
18. Limroongreungrat K, Huang YW. Pasta products made from sweet potato fortified with soy protein. LWT- Food Science and Technology. 2007; 40(2):200-206.
19. Maldari M, Maldari C. Design and performance of pasta dies. Cereal Food World. 1993; 38:807-810.
20. Manthey FA, Schorno AL. Physical and cooking quality of spaghetti made from whole wheat durum. Cereal Chemistry. 2002; 79(4):504-510.
21. Manthey FA, Yalla SR, Dick TJ, Badaruddin M. Extrusion properties and cooking quality of spaghetti containing buckwheat bran flour. Cereal Chemistry. 2004; 81(2):232-236.
22. Marti A, Pagani MA, Seetharaman K. Textural attributes of wheat and gluten free pasta. In: Dar, Y.L., Light, J.M. (Eds.) Food texture Design and Optimization, first ed. John Wiley and Sons, Ltd, UK, 2014, 234.
23. Merrill AL, Watt BK. Energy value of foods: basis and derivation, In: Agriculture handbook, No. 74. United States Department of Agriculture, Washington, 1973, 2-4.
24. Petitot M, Boyer L, Minier C, Micard V. Fortification of pasta with split pea and faba bean flours: Pasta processing and quality evaluation. Food Research International. 2010; 43(2):634-641.
25. Pollini CM, Panto F, Nespoli A, Sissons M, Abecassis J. Manufacturing of pasta products, In: Sissons, M., Abecassis, J., Marchylo, B. and Carcea, M. (Eds.), Durum Wheat Chemistry and Technology, second ed. AACC International, St. Paul, MN, USA, 2012, 164-165.
26. Resmini P, Pagani MA, Dalbon G. The influence of raw material characteristics and of pasta processing conditions on quality of pasta products. Tecnica Molitoria. 1988; 39(5):425-436.
27. Resmini P, Pagani MA. Ultrastructure studies of pasta. A review, Food Microstructure. 1983; 2(1):1-12.
28. Tiwari A, Jha SK, Pal RK, Sethi S, Krishan L. Effect of pre-milling treatments on storage stability of pearl millet flour. Journal of Food Processing and Preservation. 2014; 38:1215-1223.
29. Zweifel C, Handschin S, Escher F, Conde-Petit B. Influence of high temperature drying on structural and textural properties if durum wheat pasta. Cereal Chemistry. 2003; 80(2):159-167.