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Pasta: Raw materials, processing and quality improvement

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Abstract
Pasta is a ready to eat extruded product having higher nutritional properties. It is really suited for daily balance diet because of the higher concentration of unsaturated fatty acid. Mixing, extrusion, drying, cooling and packaging are the major steps used in the production of pasta. Pasta can be produced from different cereals like sorghum, maize, wheat, rice, oats and the addition of these cereals can change the textural, functional, physiochemical properties and microstructure of pasta. The yellow colour is the most acceptable range of pasta by customers. Pasta helps to Lower glycaemic index and type 2 diabetics and reduce abdominal obesity. Pasta is a nutritious food helps to reduce the risk of developing Alzheimer's disease.This review paper provides an updated information about the different cereals used, fortification of pasta with different plant and animal sources, production technologies, effect of thermal treatments, extrusion conditions, microstructure, and colorimetry of pasta.

Keywords: Extrusion, cereals, fortification, microstructure, pasta

1. Introduction

Pasta is a high energy sourcing food which contains high amount of carbohydrates, moderate protein and low fat. According to International Pasta Organisation (www.internationalpasta.org/index.aspx) [98], 165 million tons of pasta were produced in the world in 2020. The highest production of pasta is in European countries which is about 31%, Cenral and south America 19%, Other European countries17.5%, Africa 14.1%, North America 12.8%, Middle east 3.6%, Asia 1.5% and lowest in Australia which is about 0.3%. The fat present in pasta is unsaturated so; it does not cause any adverse effect on body (Giacco *et al*., 2016) [44].

Pasta is an ancient ready to eat product made from durum wheat, water by using a high capacity cold extruder with different types of dyes to ensure different shapes of product. It contains carbohydrates, proteins, Vitamin-B Complex, iron whether it is low in sodium, amino acids and total fat (Giacco *et al*., 2016) [44]. Semolina pasta contains about 74% of carbohydrate, 11-12% of protein, 2% of fat and 12% of water (Bepary *et al*. 2012). The Uncooked pasta contains about 68.2g starch, 11 g protein, 4.3 g soluble sugar, 2.8 g fibre and 1.4 g fat which provides 353 kcal (Giacco *et al*. 2016) [44].

Wheat pasta is the most commonly available pasta all over the world. Wheat is the most commonly consumed grain in the world (Shewry *et al*., 2009) [80]. According to FAO statistics [37], the world production and utilization of wheat grains in 2019-2020 is about 762 and 758 million tonnes and in 2020-2021 the production and utilization is forecasted about 761.7 and 757.6 million tonnes respectively. The Climate and soil are the two major factors which always tend to change the nutritional composition of wheat. Wheat contains about 12.1% water, 70.2% carbohydrate, 11.9% protein, 2% fat, 1.8% minerals and 2% crude fibres (Shewry *et al*., 2009) [80]. Thiamine, niacin and riboflavin are the nutrients which are lost during the processing of wheat grains from germ and bran. After milling, 72% of wheat grains are retained as usable four. By prolonged storage of graham flour made from whole kernel, wheat can become rancid due to the germ oil present in it (Fuad *et al*., 2010) [41].

Mixing, extrusion, cooling, packing are the major steps in the production of pasta. Cold extrusion method is commonly used here. After drying process, the product retains 10% of moisture in it (Cubadda *et al*., 2007) [27]. Major things that should be take care for high quality of pasta are proper selection of raw materials, other additives and ingredients, Processing line and packaging requirements.

Some studies are done based on the adding supplements like proteins into pasta to improve the nutritional quality.

Pasta was first produced in United States followed by countries like Canada and European Union. Durum wheat is the major source of wheat for the production of pasta in European countries. Spaghetti and macaroni are two varied pasta products produced. In 2005, the price of durum wheat becomes high and it adversely affected the retail sales of pasta. The retail sale of pasta in India becomes much low comparing with other Asia pacific region and much low in Singapore and Vietnam. Due to the lower demand, pasta was least available in India and so, the knowledge based on pasta products is comparatively low in India (Fuad *et al*., 2010) [41].

The inevitable ingredients in wheat pasta are semolina and water and other ingredients like egg, oil are optional (Bustos *et al*., 2015) [18]. Durum wheat is used for pasta because of the higher level of gluten and inelastic in nature. It can be changed to different shapes by using a dye in extruder. Durum wheat is the most common and suited wheat for pasta production because of low lipoxygenase activity, high protein content and high yellow pigment. The rheological properties of durum winter wheat are also suited for the production of pasta (Fuad *et al*., 2010) [41].

The major properties of durum wheat that influence pasta quality include the degree of refinement extracted from wheat, degree of resistance of wheat from breakage and cooking tolerance (Marconi *et al*., 2002) [60]. Durum wheat is always preferred for the production of pasta because of the uniform particle size and good textural properties of pasta. Semolina is the combination of small cell units produced from the starchy endosperm of wheat plant. The major qualities to get best quality of pasta are good yellow colour, bran specks with uniform granulation and moisture content of 13.49–14.47% (Fuad *et al*., 2010) [41].Pasta are very useful in fighting breast cancer, Alzheimer's disease, type 2 diabetics, reduce chances of abdominal obesity and it helps to reduce glycaemic index of a meal (Giacco *et al.*, 2016) [44].

In this review paper, different cereals used, fortification of pasta with different plant and animal sources, pasta production technologies, effect of thermal treatments and extrusion conditions, microstructure and quality characteristics and colour of pasta are discussed in detail.

2. Different cereals used in pasta

According to Palavecino *et al*., 2020 [69] sorghum is the major ingredient used for the production of pasta instead of wheat because of the need of gluten free products. The presence of tri dimensional protein network is comparatively low in sorghum protein and the network is much stronger enough in wheat (Schober *et al*., 2007) [76]. The Inevitable agents which possess structure in the gluten free pasta are gelatinized starch. The Pregelatinized corn starch helps to reduce cooking loss. The addition of potato flour in to sorghum helps to reduce cooking time and cooking loss. The addition of maize flour helps to increase water absorption in sorghum and helps to change the structure of protein present in pasta. A formulation of 50-60% of sorghum flour and 40% of wheat mixed with gingelly seed are prepared to improve the nutritional properties of pasta. The gingelly enriched pasta contains more nutrients than normal sorghum pasta. The gingelly enriched pasta contains more protein (10.45%), fat (2.31%), Carbohydrate (85.2%) comparing to other nutrients. The formulations of different cereals flours like soya, locust beans (high protein cereals) with gums produce low starch and low protein digestibility having similar cooking parameters with the durum pasta (palavecino *et al*., 2020) [69].

According to the study of paula *et al*., 2017 [32], Pasta is made using barley and semolina flour at different proportions. There are four formulations 100% barely flour, 50% barely flour and 50% semolina flour, 30% barley flour and 70% semolina flour and 100% semolina flour. The ingredients used to improve the taste; colour and texture of the product are annatto solution, Xantan gum and salt. Rapid visco analyser is the instrument used to detect the pasting properties of flour. The normal barely flour, waxy barley flour and semolina have a beta glucan content of about 5.9%, 9.9% and 0.31%.The normal barely flour have a higher peak viscosity of about and 3585 cP (centipoise) followed by waxy barley flour (3579cP) and semolina (1493 cP). At different pasting temperature, Semolina, waxy and normal barley flour have one peak velocity but, waxy barely flour bended with semolina have double peak velocity.

According to Balet *et al*., 2019 [9], the major factor for the determination of pasting properties using rapid visco analyser is amylose content. During heating, the structure of starch will be degraded due to low amylose content and suppresses swelling. At low temperature, the waxy starch rapidly swells and degrades at low temperature. The pasting temperature and peak time are lower in waxy barley (55°C and 5.7 min) followed by normal barley (76°C and 9.4 min) and semolina flour (85°C and 8.8 min). Thus we find that semolina flour have higher amylose content (paula *et al*., 2017) [32].

According to Marti *et al*., 2010 [61], the milled rice pasta obtained from extrusion cooking has water absorption capacity of 75.91% followed by brown rice pasta by conventional cooking (68.9%), brown rice pasta by extrusion cooking (62.4%) and milled rice pasta by conventional extrusion (61.8%). The firmness is higher in rice pasta by extrusion cooking (1529.2 N) followed by brown rice pasta by extrusion cooking (796.2 N), rice pasta by conventional cooking (525.5 N) and brown rice pasta by conventional extrusion (367.5 N). The springiness of rice pasta by extrusion cooking is about 7062.0 N mm followed by brown rice pasta by extrusion cooking (4482.7 N mm), rice pasta by conventional extrusion (3131.3 N mm) and brown rice pasta by conventional extrusion (2408.3 N mm).

Rafiq *et al*., 2017 [71] discussed on degree of gelatinization and functional properties of cereal legume pasta. The Brown rice flour is used for the production of pasta here. The in-vitro digestibility of brown rice legume pasta is ranging from 15.00 to 26.77g/100g. The highest in-vitro starch digestibility was at 36% feed moisture and 110°C barrel temperature (26.77g/100g).When an increase in feed moisture from 28 to 36% took place the starch digestibility also increases by 28.25% at 110°C barrel temperature. The in-vitro protein digestibility of brown rice legume pasta is ranging between 50.35 to 84.83 g/100g.With increase in barrel temperature and feed moisture, increase in protein digestibility will take place. When barrel temperature increased from 70-110°C, the protein digestibility increase by 21%.The degree of gelatinisation of semolina brown rice legume pasta is from 52.13-90.10%. The higher value of degree of gelatinisation was observed at 36% feed moisture, 110°C barrel temperature and lowest value was at 28% feed moisture and 70°C barrel temperature.415 cP (centripoise) was the highest peak viscosity of semolina brown rice legume pasta at 28% feed moisture, 70°C barrel temperature and the temperature increased to 110°C where peak velocity changed to 310 cP.

The gruel solid loss of semolina-brown rice legume pasta is ranging from 6.11 to11.6%. The firmness of semolina brown rice legume pasta ranges from 7.23 to15.1 N. The products having higher feed moisture shows higher firmness.

According to Infante *et al*., 2010 [42], spaghetti pasta with Mexican common bean flour is prepared. Spaghetti with different formulation of common bean flour is prepared here. The formulations of common bean flour are 0%, 15% and 30%. By the addition of 30% common bean flour, decrease in moisture content will take place and by the addition of 15% common bean flour there was no change in moisture. As the concentration of common bean flour increases the protein content also increases, 16.67% of protein was present in pasta containing 30% of common bean flour. Pasta with 0% of common bean flour have higher water absorption capacity (29.90 ml/g) at 80°C followed by pasta with 15% of common bean flour (28.85 ml/g) at 60°C.

Rafiq *et al*., 2017 [71] says that higher temperature cooking of pasta have greater influence on cooking loss. But the result of Infante *et al*., 2010 [42] was quite different. In normal pasta, at higher temperature increase in cooking loss takes place. But by the addition of 15% of common bean flour there was no influence in cooking loss and in 30% of common bean flour the cooking loss greatly decreases. The firmness was lower in 30% common bean flour at lower temperature (60°C) comparing with 15% common bean flour and normal spaghetti pasta. The Furosine content (mg/100 g of protein) was higher in 30% of common bean flour at 80°C (77.0 ± 0.01) and lower in normal spaghetti pasta at 70°C (25.5 ± 0.57).The total phenolic content (mg of catechin equivalent/g of sample) was higher in 30% of common bean flour pasta at 70°C (9.68 ± 0.74) and lowest in normal spaghetti pasta at 60°C (4.98 ± 0.84).

A study was done based on lupin flour blended with durum wheat pasta. The formulations used are 0:100, 10:90, 20:80, 30:70, 40:60 and 50:50 (w/w).The moisture content (%) was lower in 50% lupin flour (23.3±0.2) and higher in 100% durum wheat pasta (29.0 ±0.2). The amount of water required during extrusion decreased with increase in lupin flour concentration. The cooking losses (g/100 g) was lower in 100% durum wheat pasta (6.6 ± 0.1a) and higher in 50% lupin flour (7.7 ± 0.6). The breaking strength of pasta decreased with increased in lupin concentration. The stickiness of control pasta was too low (36g) but the stickiness of pasta incorporated with lupin flour was unable to detect. As the concentration of lupin flour increases firmness decreases. A decrease of firmness from 3170 gm to 1857 gm takes place in the formulation of 50% lupin flour. Lupin flour contains high fibre which helps to break the protein starch matrix in a pasta microstructure causes reduction in firmness of pasta (Jayasena *et al*., 2011) [51].

Yadav *et al*., 2014 [99] studied about the vegetable blended wheat-pearl millet pasta. Carrot, tomato, turnip and spinach are used as vegetables here. The wheat and pearl millet are taken in the ratio of 90:10.The wheat contains 10.2± 0.15% of protein, 0.90 ± 0.05% of fat, 0.45 ± 0.02% of ash and 72.40± 0.25% of carbohydrate and pearl millet contains 10.29 ± 0.15% of protein, 3.7 ± 0.10% of fat, 1.90 ± 0.05% of ash and 63.49 ± 0.25% of carbohydrate. Comparing with other vegetables, Spinach pasta contains maximum protein of about 10.70%, 4.31 mg/100 g of iron, 190mg/100g of potassium, 21.2 mg/100 g of sodium and Carrot pasta have a maximum calcium of about 40.91mg/100 and phosphorous of 244.1mg/100gm.The cooking loss was higher in normal pasta which is about 1.4± 0.048% and lowest cooking loss was observed in tomato incorporated pasta which is about 1.02 ± 0.046%.Vegetable incorporated pasta have more water absorption capacity comparing with normal pasta where turnip have maximum water absorption capacity which is about 180.1 ± 4.78 and minimum for normal pasta which is about 113.09± 4.42.As the storage time increases, The water absorption ability also increases. The maximum water absorption ability was in turnip which is increased from 180.1 ± 4.78 to 197.1 ± 2.13. The firmness value of spinach is about 37.31± 2.28 N and 30.91 ± 1.21 N for carrot which is comparatively higher than normal pasta. Comparing with other pastas carrot pasta (8.8 ± 0.70) has higher stickiness and tomato pasta (4.5 ± 0.62 N) has lower stickiness.

Table 1: Nutritional properties of different types of pasta

Different types of pasta	Moisture (%)	Protein (% d.m.)	Fat (% d.m.)	Carbohydrates (% d.m.)	Ash (% d.m.)	Crude fibre	References
Wheat semolina pasta	8.9 ± 0.2	12.6 ± 0.2	2.0 ± 0.1	79.0 ± 1.2	0.84 ± 0.04	2.84 ± 1.17	Pasquale *et al*., (2021) [31] Giménez *et al*., (2011) [45]
Sorghum pasta	10.02 (g)	9.6 (g)	0.84 (g)	74.7 (g)	-	1.02 (mg)	Benhur *et al*., (2015) [11]
Black rice bra fortified pasta		10.98 ± 0.02	2.97 ± 0.14	-	-	3.60 ± 0.03	Sethi *et al*., (2020) [78]
Cricket powder enriched pasta	-	16.92 ± 1.01	4.73 ± 0.32	73.42 ± 1.02	1.46 ± 0.08	-	Duda *et al*., (2019) [35]
Wheat enriched gluten free egg pasta	32.86 ± 0.18	13.45 ± 0.11	1.33 ± 0.22	50.65	0.74 ± 0.01	≤0.1	Hager *et al*., (2012) [49]
Teff enriched gluten free egg pasta	31.59 ± 0.06	17.85 ± 0.11	2.04 ± 0.01	46.88	1.64 ± 0.04	0.55 ± 0.14	Hager *et al*., (2012) [49]
Oats enriched gluten free egg pasta	32.01 ± 1.58	13.02 ± 0.25	4.85 ± 0.01	48.49	0.81 ± 0.07	1.00 ± 0.49	Hager *et al*., (2012) [49]
Carrot enriched pasta	-	10.5 ± 0.205	1.30 ± 0.041	75.3 ± 0.221	0.99 ± 0.064	0.76 ± 0.026	Yadav *et al*., (2014) [99]
Tomato Enriched pasta	-	10.6 ± 0.118	1.28 ± 0.047	74.1 ± 0.188	0.89 ± 0.062	0.64 ± 0.010	Yadav *et al*., (2014) [99]
Defatted soya flour-broken rice pasta	11.27 ± 0.02	16.32 ± 0.04	0.81 ± 0.02	70.45 ± 0.06	1.07 ± 0.05	2.65 ± 0.07	Udachan *et al*., (2017)
detoxified matri flour	10.50 ± 0.03	15.50 ± 0.21	1.39 ± 0.01	-	0.96 ± 0.01	1.13 ± 0.11	Ahmad *et al*.,

enriched pasta							(2018) [2]
Onion powder enriched pasta	11.670.03	10.2170.05	1.3570.02	-	8.9670.03	-	Rajeswari *et al.*, (2013) [73]
Amaranth flour enriched pasta	8.13 ± 0.05	15.05 ± 0.10	6.68 ± 0.08	-	2.91 ± 0.08	4.80 ± 0.02	Chauhan *et al.*, (2017) [22]
Rice flour pasta	28 (%)	7.92 ± 0.004	2.3 ± 0.01	87.1	1.37 ± 0.02	1.31 ± 0.01	Bouasla *et al.*, (2016) [17]
Yellow pea flour pasta	30 (%)	23.48 ± 0.02	1.23 ± 0.01	69.35	2.9 ± 0.04	3.03 ± 0.03	Bouasla *et al.*, (2016) [17]
Millet-pomace based pasta	9.00 ± 0.61 (gm)	10.16 ± 0.85 (gm)	6.00 ± 0.42 (gm)	70.84 ± 1.18 (gm)	0.80 ± 0.05 (gm)	3.20 ± 0.24 (gm)	Gull *et al.*, (2016)) [47]

Table 2: Functional properties of different types of pasta

Different types of pasta	Optimal cooking time	Water absorption (g/100 g)	Cooking loss (g/100 g)	Swelling index (g/g)	References
Wheat semolina pasta	9.7 ± 0.2 (min)	128.6 ± 1.2	4.70 ± 0.12	0.11 ± 0.01	Pasquale *et al.*, (2021) [31], Kamble *et al.*, (2020) [52]
Black rice bran fortified pasta	4.30 ± 0.00 (min)	101.86 ± 1.68	6.69 ± 0.04	1.34 ± 0.02	Sethi *et al.*, (2020) [78]
Common bean flour enriched pasta	3.31 ± 0.10 (min)	25.65 ± 0.15	19.44 ± 0.40	-	Infante *et al.*, (2010) [42]
Sorghum pasta	9.0 ± 0.40 (min)	86.20 ± 3.50	10.12±0.14	-	Benhur *et al.*, (2015) [11]
Blue maize enriched gluten free pasta	7.67 ± 0.58 (min)	131.18 ± 10.78	10.68 ± 1.11	-	Méndez *et al.*, (2018) [19]
grape peel powder enriched pasta	5.33 ± 0.05 (min)	219.23 ± 0.55	15.25 ± 0.28	0.27 ± 0.01	Iuga *et al.*, (2020) [93]
Carrot leaf meal and oregano leaf meal enriched pasta	435 ± 36 (Second)	164.49± 1.62	8.35 ± 0.23	-	Boroski *et al.*, (2011) [15]
Diacronema vlkianum enriched pasta	3 (min)	82.0 ± 4.2	3.9 ± 0.1	0.9 ± 0.1	Fradique *et al.*, (2013) [39]
detoxified matri flour enriched pasta	10.0 (min)	69.2 ± 1.2	5.8 ± 0.1	1.50 ± 0.01	Ahmad *et al.*, (2018) [2]
Yellow pea flour enriched pasta	4.83 ± 0.02a (min)	78.2 (%)	6.38±0.12	-	Shreenithee *et al.*, (2013) [82]
Microalgae incorporated pasta	8 (min)	96.6 ± 7.3	4.0 ± 0.6	1.2 ± 0.1	Fradique *et al.*, (2010) [40]
Millet-pomace based pasta	6.00 ± 0.12	202 ± 2.40	6.10 ± 0.16	2.58 ± 0.15	Gull *et al.*, (2016)) [47]

According to Méndez *et al.*, 2018 [20], a study was conducted on the production of gluten free pasta using blue maize flour. Chickpea, blue maize, white maize are used to make this type of pasta. An increase or decrease in the level of maize flour does not affect the cooking quality of pasta. Through this study we found that there will be no change in the cooking quality of pasta by replacing blue maize with white maize or vice versa. Méndez *et al.*, 2018 [19] found a small difference in the amylose and protein content of blue and white maize. The pasta containing 75% of blue maize has higher total phenolic retention after extrusion than white maize. The pasta containing 20 to 30% blue maize shows a decrease in total phenolic content after extrusion. The blue maize pasta has a decrease in total phenolic content, antioxidant capacity and cooking loss after extrusion.

3. Fortification of pasta with different plant and animal sources

Food fortification is the incorporation of nutrients in to the food whether it already present in it or not (Mkambula *et al.*, 2020) [66]. The major different between enrichment and fortification is enrichment is the addition of nutrient which is already present in it whether it is removed during processing. Microbial fortification, commercial fortification, home fortification, industrial fortifications are different types of fortification. Food fortification helps to reduce the Micronutrient deficiencies and improved the health condition of specific conditioned people (Liyanage *et al.*, 2011) [56].

In the study conducted by Majewska *et al.*, 2020 [64], Fortification of semolina flour with onion skin cultivated from Polanowska cultivar take place. The onion skin is peeled and it is passed through a mesh screen of 0.5mm. 0% (m/m), 2.5% (m/m), 5% (m/m) and 7.5% (m/m) of onion skin are the formulation used here. Onion is an abundant source of phenolic acid where it contains 25 different types of flavonoids. Quercetin 3, 4-diglucoside, isorhamnetin 3, 4-diglucoside, quercetin 3-glucoside, quercetin 4-glucoside, quercetin aglycone and phenolic acids present in it. quercetin 4-glucoside is the major phelonic acid present in fortified dry pasta. Even after cooking, the outer layer of onion contains large amount of flavonoids.

Sharma *et al.*, 2015 [79], an increase in the total phenolic content was observed after thermal treatment at 100°C. Due to the presence of glycosidic bond or hydrolysis of ester, the release of phenolic compounds in powdered onion happens. The quercetin is largely present in the epidermis region of onion and during the storage of dry onion the glycoside of quercetin is converted to quercetin. Lesjak *et al.*, 2018 [55], these organo sulfur compounds like quercetin have a potential to prevent obesity. According to Majewska *et al.*, 2020 [64], Onion skin have high antioxidant activity comparing with semolina and the fortification of semolina flour with onion skin shows an increase in the antioxidant activity of the fortified pasta.

Kowalczewski *et al*., 2015 [53] shows the production of durum wheat pasta fortified with potato juice where the ingestion is in two forms; dried and fresh potato juice. The protein, fat, moisture content and other functional ingredients present in pasta greatly influences the cooking loss (Fradique *et al*., 2013) [39]. The potato juices are very useful to prevent dyspeptic symptoms. But only 20% people achieved complete relief from the disease (Chrubasik *et al*. 2006) [24]. Pro vitamin A, Vitamin B_1, Vitamin B_2, Vitamin B_6, Nicotinic acid amide, Vitamin C and dehydroascorbinic acid are the major source of vitamins present in potato (Vlachojannis *et al*., 2010) [95].

The cooking loss (%) is higher in dried potato juice added pasta (5.8 ± 0.8) followed by control pasta (4.5 ± 1.2) and fresh potato juice added pasta (0.6 ± 0.2). The firmness (N/mm) is more in dried potato juice added pasta (1.42 ± 0.12) followed by fresh potato juice added pasta (1.22 ± 0.05) and control pasta (1.10 ± 0.11).The consumer sensory acceptance was higher in control pasta (7.00 ± 0.24) followed by fresh potato juice added pasta (6.80 ± 0.32) and fresh potato juice added pasta (5.70 ± 0.33) (Kowalczewski *et al*., 2015) [53].

Shogren *et al*., 2006 [81] shows fortification of spaghetti with soya flour at different concentrations. By the addition of 25% soya flour into spaghetti an increase of protein content from 15-25% and 5% addition of corn gluten meal increases the protein content by 1%.The protein present in 35% spaghetti fortified with soya is double of the protein present in original spaghetti. The presence of essential amino acids like lysine, threonines are highly present in spaghetti fortified with soya. The major amino acids present in soya fortified spaghetti are aspartic, Threonine, Serine, Glutamic, Proline, Glycine, Alanine, Cystine, Valine, Methionine, Isoleucine, Leucine, Tyrosine and phenylalanine (Bos *et al*., 2003) [16]. The globulin type proteins present in soya bean are α-Conglycinin, β-Conglycinin, poly-glycinin and glycinin (Clarke *et al*., 2000) [25].

The moisture content (10.09%) and crude protein (33.50%) was higher in 50% soya and 50% durum wheat pasta. Crude fat (0.38%) and crude fibre (0.55%) was higher in 25% soy + 70% durum + 5% corn gluten meal combination. The Moisture content (9.74%) and crude protein (15.36%) are lower in 100% drum pasta. The Crude fat (0.13) and Crude fibre (0.34%) are low in 25% soy + 75% durum formulation. Also similar firmness (mean intensity score) of 4.3 was observed in 25% soy + 75% durum, 25% soy + 70% durum + 5% corn gluten meal, 35% soy + 65% durum and 50% soy + 50% durum (Shogren *et al*., 2006) [81].

Monteiro *et al*., 2016 [67] discussed the fortification of durum wheat pasta with tilapia flour. 0%, 6%, 12%, 17%, 23% are the formulation of tilapia flour used in it. The moisture content was higher in 0% tilapia flour (7.69 ± 0.28%) and lower in 23% tilapia flour (4.42 ± 0.22%). The protein content is higher in 23% tilapia flour (47.91 ± 0.11%) and lower in 0% tilapia flour (15.77 ± 0.84%). The carbohydrate content is higher in 0% tilapia flour (72.28 ± 1.24%) and lower in 23% tilapia flour (40.83 ± 0.94%). The energy value (kcal/100g) was higher in 23% tilapia flour (404.04 ± 5.91) and lower in 0% tilapia flour (380.99 ± 3.46). The major amino acids present in tilapia are arginine, Histidine, Isoleucine, Leucine, Valine, Tryptophan, Methionine, Lysine and Threonine (Sayed *et al*., 2004) [36]. According to Mjoun *et al*., 2010 [65], Thiamine, riboflavin, pantothenic acid, pyridoxine, niacin, biotin, folic acid, inositol, choline, ascorbic acid, retinol and tocopherol are the major vitamins present in tilapia.

According to Ahmad *et al*., 2018 [2], fortification of durum wheat semolina with detoxified matri flour is done. The addition of detoxified matri flour was in the formulation of 5, 10, 15, 20 and 25% into durum wheat semolina. The moisture content (10.50 ± 0.03%) was higher in 25% detoxified matri flour (10.26 ± 0.10) and lower in 5% detoxified matri flour. The lipid content (1.39 ± 0.01%) is higher in 25% detoxified matri flour and lower in 5% detoxified matri flour (1.31 ± 0.17%). Also the protein, Nitrogen free extract, fibre and ash content are higher in 5% detoxified matri flour and lower in 25% detoxified matri flour. The highest optimum cooking time (min) is for 5% detoxified matri flour (11.9) and 25% detoxified matri flour need lowest cooking time (10). Also the cooking loss for 25% detoxified matri flour (5.8 ± 0.1%) are lower and 5% detoxified matri flour possess highest cooking loss (5.3 ± 0.3%). According to Ramachandran *et al*., 2008 [74] Tannin, Phytic acid and trypsin inhibitor are the anti-nutritional factors present in matri. Also, the matri flour before processing contains neurotoxin and α-ODAP which cause paralysis in lower limbs or tiredness in muscles (Grela *et al*., 2001) [46].

Boroski *et al*., 2011 [15] says about the fortification of wheat flour with oregano leaf and carrot leaf meal shows higher antioxidant activity after the addition of 10% oregano leaf. Spices always possess higher antioxidant activity comparing with other natural sources. The phenolic content (mg GAE 100 $g^{-1)}$ was higher after the addition of 10% carrot leaf meal and 10% oregano leaf (283.22 ± 12.44) and lower in the formulation where oregano leaf where not added (120.89 ± 5.87).

According to Grijalva *et al*., 2018 [48], Apigenin, luteolin, scutellarein, apigenin-7-O-glucoside, luteolin-7-O-glucoside and luteolin-7-O-glucuronide are the major flavones present in oregano spices. It have anti-inflammatory, antioxidant, anti-asthmatic, anti-ulcer, decreased risk of cardiovascular diseases, anti-diabetic, anti-cancerous properties. Catechin, pyrogallol, Catechol, Syringic acid, Gallic acid, Vanillic acid, Coumaric acid, Hydroxybenzoic acid, Chlorogenic acid, Caffeic acid, Chrisin and rosmarinic acid are the major polyphenol components present in oregano determined by HPLC analysis (Damasius *et al*., 2014) [28].

4. Pasta production technologies

Extrusion is a process of producing different shaped products by passing it through a die by using specific blades. The mix that is passed through the die is an extrudate and the machine part which applies force to the mix to pass through it is known as an extruder (Bordoloi *et al*., 2014) [14]. According to Choton *et al*., 2020 [23], Cold extruders and hot extruders are two types of extruders based on method of operation and single and twin screw extruders are the extruders based on construction. Cold extrusion is commonly used for pasta production where the temperature will be less than 50° C (Manthey *et al*., 2006) [59].

According to Teterycz *et al*. 2020 [91], lamination technology is used for the production of pasta. The dough was mixed using a mobile mixer and the water and other ingredients are added into it by increasing temperature to about 30° C. An Atlas 180 pasta making machine is used to adjust the thickness of dough sheet. The dough is drying at a temperature of 40° C for 2 minutes having length of 500 mm long and width of 7 mm. It is dried using a static drier after placing it in to the sleeves for 7 hour. The final drying temperature is about 55° C where relative humidity ranging from 75% to 55%.

Alamprese *et al*. 2005 [4] uses an automated plant for the preparation of pasta (P. Nuova, La Monferrina, Asti, Italy).The dough produced was fed into a pasta rolling machine which provides a smooth texture to the pasta. Then, the dough is converted into sheets having 1mm thickness. Loose pasta, Pasteurized pasta, double pasteurized pasta are the common pastas made through this method. According to Alamprese *et al*., 2008 [3], to prevent the moisture loss of loose pasta, the sheets are placed in an airtight container and the analysis is done in the same day of production. For pasteurized pasta, Sheets are placed inside a lasagne cooling device in an autoclave setted at a temperature of 95°C for 1 min. Then it is dried for about 15 minute in room temperature and packaged using poly ethylene bags which are sealed under partial vacuum condition. Before analysing, the pasta is kept for at least 6 days at 4° C. In case of double pasteurised pasta, it undergoes a secondary thermal treatment at 93°C for 1 hour. It is kept at 4° C for 7 days before analysis.

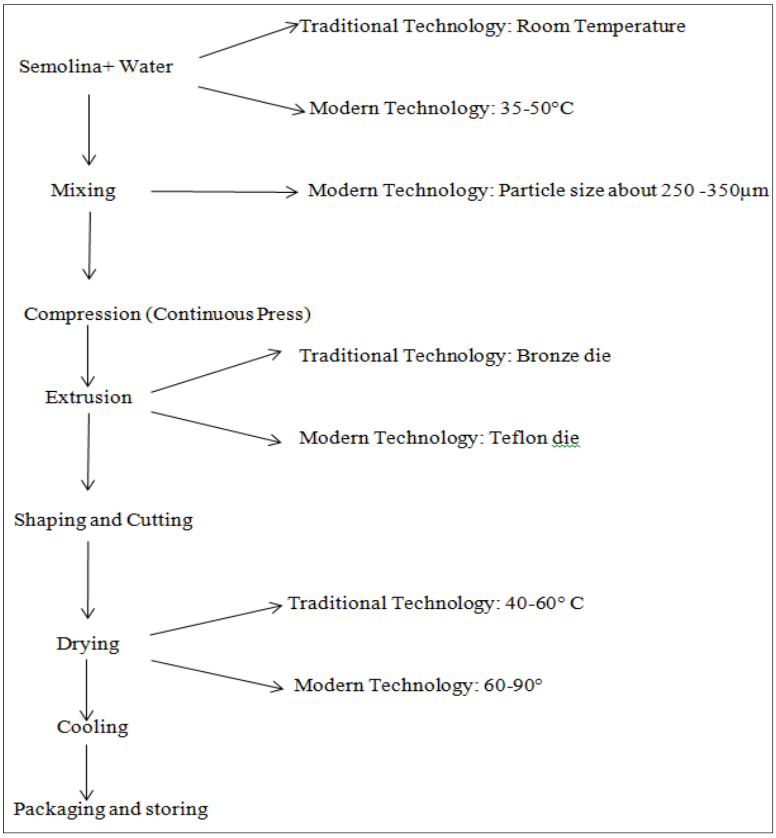

Fig 1: Wheat pasta production process. (Sicignano *et al*., 2015; Arcangelis *et al*., 2020) [29, 83]

Zardetto *et al*., 2006 [101] explains the pasta production using a continuous press (model K500, Monferrato, Asti, Italy) consist of circle shaped puncture and metal die. This process is done at a partial vacuum of 300 mmHg. A sheet rolling machine is used for the dough to convert it into a sheet having 1cm thickness. Then it is passed to a second cylinder having rotational speed of 3.5 rpm having thickness of 0.90 mm. After this process, the pasteurization takes place at 99°C for 1 minute with working pressure of 9120 pa.

According to Sobota *et al*., 2020 [84], MAC 30s lab pasta extruder made from Italy is used to make Tagliatelle pasta. The mixing of dough takes place for 15 minutes at atmospheric pressure. The temperature of cylinder was about 30°C, external pressure is 12 MPa and temperature of die is 40°C are the important criteria used for making pasta. Pasta is dried and rolled into shape and placed in the chamber. EAC30-LAB static pasta dryer made from Italy is used to dry the product. The total time taken for drying is about 7 hour.

Schoenlechner *et al*., 2010 [77] explains the production of pasta using noodle press (laboratory) made from Italy model number P3. Kitchen Aid Professional Mixer, Model KPM50, USA speed-1 is used to mix the ingredients and water to obtain smooth and firm dough. The Kneading of dough was done at speed-1 for 15 minutes. The pasta produced is placed in the sleeves and dried at 42° C for 9 hours. The pasta is stored in airtight package stored at 4°C. According to Benhur *et al*., 2015 [11], Single screw extruder with Low temperature short time made from Italy is used. Extrudate with good texture and good internals are used to improve the process variables of cooking. The moisture equilibrium can be achieved by mixing the ingredients with water by spraying for 30 minute. The feed rate was about 15kg/h, shearing force 600 rpm and die diameter was about 6.5 mm. The temperature of die was adjusted to 55°C.The product is collected and it will be dried in tray drier at 60°C.

Arribas *et al*., 2020 [7] explains the pasta production using continuous pilot scale extruder from Italy. Here the blending of rice with beans is done using a blender named Thermomix TM-31 from Germany which helps to allow homogenous dough formation. The continuous pilot scale extruder works at constant speed for 15 minutes. To produce an experimental fettuccine having 20 cm length, a cold extruder having temperature of 30°C is used. The pasta is pre-dried at room temperature for 30 minute and then kept it in an oven for about 2 hour at 70°C. According to Rafiq *et al*., 2017 [72], Single screw extruder is used to make gluten free pasta from brown rice. A co-rotating intermeshing twin screw extruder model BCH from France is used here. The barrel diameter is about 2.5 mm and the ratio of length to diameter is 16:1.The working speed varied from 0 to 681 rpm and the motor is working at 8.5 kilowatt. The extruder contains a torque indicator which shows how much current drawn from drive meter which shows as a percentage of torque.

Table 3: Properties of pasta extruded using different types of die at different temperature

Parameters	Bronze die			Teflon die			References
	40 °C	50°	80 °C	40 °C	50 °C	80 °C	
Moisture (g-water 100g-dry matter^{-1})	13.0 ± 1.0	47.9 ± 0.7	9.1 ± 0.8	14.8 ± 1.2	45.7 ± 1.1	8.5 ± 1.8	Lucisano *et al*., (2008) [57]
Diameter (mm)	2.60 ± 0.01	2.80 ± 0.20	2.49 ± 0.02	2.44 ± 0.01	2.64 ± 0.02	2.34 ± 0.01	Mercier *et al*., (2011) [63]
Apparent density (g cm^{-3})	1.176 ± 0.054	1.228 ± 0.064	1.324 ± 0.013	1.275 ± 0.001	1.30 ± 0.010	1.366 ± 0.005	Mercier *et al*., (2011) [63]
Porosity (-)	0.175 ± 0.034	0.05 ± 0.05	0.082 ± 0.012	0.108 ± 0.005	0.00 ± 0.01	0.056 ± 0.006	Lucisano *et al*., (2008) [57]

Sobukola *et al*., 2012 [85] explains the production of yam starch based pasta using laboratory scale single screw extruder having 16:1 as length per diameter, 18.5 mm screw diameter, length of 304 mm and power of about 0.25 hp. Transmission zone and die zone are the two main section in the extruder. Band heaters are used to heat the barrel present in the extruder. The screw speed of extruder is about 100-140 rev/min and the die temperature ranging from 100-110°C.The extrudate is kept in room temperature and sealed it in using poly ethylene bag.

5. Effect of thermal treatments and extrusion conditions of pasta

Zweifel *et al*., 2000 [103] explains the thermal stability of pasta at high thermal conditions. Pasta contains proteins, vitamins where only small enthalpy loss will take place. During thermal treatment, the extruded spaghetti have low gelatinization tendency at 60°C and 5.4 j/g comparing with normal spaghetti and the melting range was increased by 2.6°C when temperature increased by 2.3°C. After 2 hour of drying the gelatinization temperature was decreased by 1.3 °C at 55°C. Waterhouse *et al*., 2013 [87] says the antioxidant activity, flavonoid content and total phenolic content are higher in cooked pasta comparing with uncooked pasta. The damages caused due to thermal treatment are mainly determined by furosine content (Gasparre *et al*., 2019) [43]. Laishram *et al*., 2017 [54] explains the treatment of pasta containing black rice using microwave, conventional and sous-vide methods. As the temperature increases the cooking yield also increases in case of conventional and sous-vide methods. Sous wide method is a cooking process which is done by using vacuumized pouches at controlled temperature conditions (Baldwin *et al*., 2012) [8].The cooking yield of black rice pasta was increased from 240.7 to 305.9% in conventional treatment and an increase from 252.48 to 354.3% take place in case of sous-vide treatment (Laishram *et al*., 2017) [54]. Anderson *et al*. 2006 [5] says that the water holding capacity, water absorption capacity and swelling power was increased when the temperature of the pasta increases, because of the thermal disintegration of amylose granules. As the microwave power increases the cooking yield of pasta decreased from 304.4 to 255.34%. The pasting temperature of pasta was 66.6 °C was increased in the range of 87 to 90 °C in case of conventional method, 86 to 92 °C for sous vide method and 83 to 92 °C for microwave treatment (Laishram *et al*., 2017) [54]. Cocci *et al*., 2008 [26] says that microwave products are softer than traditional cooked products due to high gelatinisation and low temperature comparing to others.

Table 4: Pasting properties of different types of pasta

Different types of pasta	Pasting temperature (°C)	Peak viscosity (cP)	Breakdown viscosity	Setback viscosity	References
Durum semolina pasta	92.00	915	104	1874	Gull *et al*., (2016)) [47]
Millet-pomace based pasta	88.10	932	299	788	Gull *et al*., (2016) [47]
Multi grain flour pasta	68.71 ± 0.70	2093.00 ± 5.29	1320. 68 ± 1.53	2564.62 ± 4.16	Kamble *et al*., (2020) [52]
Amaranth flour enriched pasta	77.45 ± 0.02	94.05 ± 0.35	20.98 ± 0.34	9.93 ± 0.22	Chauhan *et al*., (2017) [22]
Rice Yellow pea pasta	31.5 ± 2.12	111.0 ± 2.83	40.5 ± 2.83	64.0 ± 1.41	Bouasla *et al*., (2018) [17]
60 hour fermented Cassava flour enriched pasta	74.33 ± 0.04	158.79 ± 3.36	67.08 ± 4.60	49.21 ± 0.18	Odey *et al*., (2020) [68]

Acquistucci, 2000 [1] Says that millard reaction can be easily take place in pasta undergoing thermal treatment. The Millard reaction take place in higher temperature dried samples and so, Non enzymatic browning reactions are formed. Low temperature (LT) dried samples always possess lower Millard reactions. The damages caused due to thermal treatment are mainly determined by Furosine content. Verardo *et al*., 2017 [94] says that in case of LT samples, spaghetti produced from Pasteurized eggs from conventional breeding and Eggs produced from hens breeded with organic methods contains furosine content lower than spaghetti produced from Spray-dried pasteurized eggs obtained from conventional breeding. High temperature samples contain 4.7 times higher furosine content than low temperature samples.

Cavazza *et al*., 2012 [21] says that friction of the sample can cause an increase in temperature. The moisture content of dough should be less than 12% for the suitable storage at room temperature. The traditional method always follows long time (24–60 h) low temperature (29–40 °C) process and high temperature (80–100 °C) short time (5–12 h or 1–2h) process. There was no carotenoid loss during extrusion at low temperature and significant loss in carotenoid take place during high temperature drying. There was about 54.7 to 80% loss in carotenoid content after drying at high temperature (Beleggia *et al*., 2011) [10].

Zardetto *et al*., 2014 [102] explains the furosine content present in fresh filled pasta at different temperature. The furosine content before treatment was higher (31.03 ± 0.78) at high temperature of 98° C for 3 minute and lower furosine content was observed (11.58 ± 1.74) at 98° C for 12 minute. The furosine content after treatment are higher (38.43 ± 6.7) at 98° C for 12 minute and lower (17.70 ± 1.04) at 88° C for 3 minute. Hidalgo *et al*. (2010) [50] says that there was more decrease in the carotenoid content of pasta produced in lab pasta extruder than industrial pasta extruder. Alamprese *et al*. 2005 [4] says that a covalent disulphide bond was produced due to the nature of proteins during the thermal treatment of egg pasta. Ovalbumin is the major soluble protein present in the egg pasta. A change in the structure of pasta will take place during the double thermal pasteurization due to tight protein network.

Marti *et al*., 2010 [61] discussed about the preparation of rice based pasta using extrusion. The parboiled rice was mixed with water and two types of extrusion processes were done. The prepared mixture was passed through an extruder having steam of about 115 °C and it is heated for 2 minute. Then it is passed through a continuous extruder which is transformed in to small pellets. The extruded milled rice pasta production increases the water absorption rate and lowers the cooking losses comparing with other pasta products. Pasta production through double steaming process is better than mono steaming process because of better cooking characteristics. Pasta produced through extrusion always possesses higher springiness, firmness and shear force. The main advantage of Extrusion cooking at high temperature of milled rice pasta is that it becomes more hydrophilic by the production of a new macromolecular structure. The cooking loss will become lower to about 4.21% and improved structure of the cooked product will take place because of the formation of a less soluble structure during the same condition.

6. Microstructure and quality characteristics of pasta

Microstructures of pasta are commonly determined using Scanning electron microscope (SEM) and Transmission Electron microscope (TEM) (Sudha *et al*., 2010) [86]. The Atomic force microscopy and Confocal fluorescence microscopy (CLSM) are used to check the microstructure of complex foods. There are different tomographic techniques used to identify the 3D microstructure of foods like X- ray computer tomography and magnetic resonance imaging (Wang *et al*., 2018) [96].

Marco *et al*., 2014 [30], discussed about the microstructural properties of wheat-spirulina pasta. It shows an increase in the structural changes of pasta after the addition of spirulina biomass. The changes take place in the structure was heterogeneous and not uniform. Also, higher concentration of spirulina causes more stickiness and solid loss. The microstructure of cooked pasta was determined by Confocal Scanning Laser Microscopy. According to Fradique *et al*. 2010 [40], the presence of gluten in wheat flour improves firmness and stickiness but in spirulina it may or may not affect the properties mentioned above. During cooking, the firmness of product is always related to hydration of starch granules. Marco *et al*. 2014 [30], says that as the addition of spirulina increases the chewiness, firmness and cohesiveness of pasta. The leaching of amylose from gelatinized starch granule always determines the stickiness of wheat products. As the addition of spirulina increases the amount of gluten present decreases and the protein network become weaker due to the leakage of amylose.

Susanna *et al*., 2012 [88] explains that the microstructure of standard pasta which explains trapped gelantizied starch granules in protein films of gluten. But in case of hypoallerginic pasta containing other cereals, discontinues network is produced because of the dilution of gluten. The flour produced from hypoallergenic and durum shows a continuous network of protein due to the entrapment of starch. The hypoallergenic pasta contains other cereals which results the presence of small granules from other sources which may or may not affect the cooking quality of pasta. The preparation of product containing multigrain shows discontinuity in protein matrix. By the addition of hydroxypropylmethyl cellulose, a continuous protein structure can be achieved (Rajeswari *et al*., 2013) [73]. According to Prabhasankar *et al*., 2009 [70], by the addition of more than 2.5% of sea weeds, discontinuous micro structured pasta is formed and addition of alginate in to pasta can improve the stability of starch and helps to prevent the dough rapture and reduce starch loss.

According to Rajeswari *et al*., 2013 [73], the gluten network of control pasta was clearly seen but a tightly embedded network is seen in the pasta containing onion powder and Gum Arabica. Gum Arabica have the potential to improve the foaming properties of gluten. Wójtowicz *et al*., 2020 [97] shows the difference in micro structure of common wheat and white spelt wheat. Scanning electron microscope is the instrument used here. The common wheat and white spelt wheat shows a homogeneous structure where the protein is entrapped in protein starch matrix. The common wheat possesses more compact and thick structure comparing with white spelt wheat. The common wheat also possess high degree of starch gelatinization. By the application of low temperature heat in durum pasta, a half gelatinized structure will be formed. In case of whole grain spelt flour and whole grain wheat flour a discontinuous structure is formed.

Bouasla *et al*., 2016 [17] discussed about the samples of rice yellow pea precooked pasta shows a corrugated microstructure. Due to the application of extrusion technique some melted materials are also seen in the pasta. The pasta having a moisture content of 32% shows a smooth surface while pasta having 28% moisture content shows a hard surface. Holes are identified in the pasta having 28% moisture content treated at 100 rpm due to the lower water availability and high shear. Tudorica *et al*., 2002 [92] says that the control pasta sample has strong and continuous strands which are made by entrapping starch molecules. They are irregular and swollen in shape. The structure of protein become discontinues by the addition of pea fiber into it. As the amount pea fiber present in pasta increases, the structures become more rough, discontinuous and highly porous. The structure of the inulin was more continuous than the structure of pea fiber and after the addition of 3% guar, the microstructure become more compact as control. Here, the protein, starch and fiber were integrating in to a compact network.

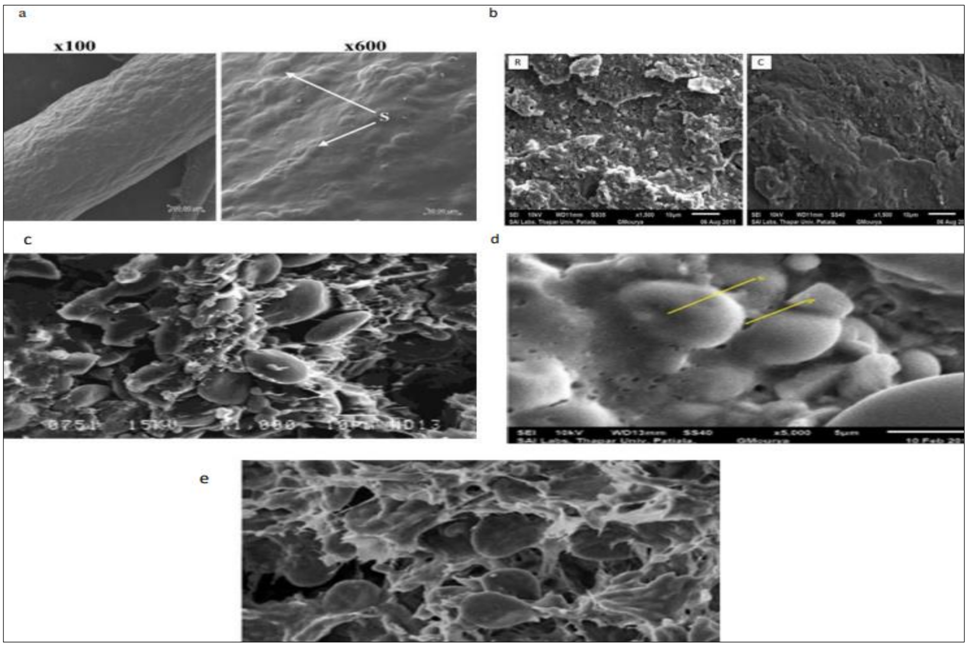

Fig 2: Scanning electron micrograph of a) White bean enriched pasta at different dimensions, b) Raw and cooked Amaranth enriched pasta, c) Pea Fibre enriched pasta, d) Millet And Carrot Pomace Based Pasta, e) Hypoallergenic pasta (Chauhan *et al*., 2017 [22]; Tudorica *et al*., 2002 [92]; Gull *et al*., 2018 [47]; Susanna *et al*., 2012) [88]

Dhiraj *et al*., 2013 [34] discussed about the structural integrity of pasta. Control pasta always has a smooth, continuous and protein starch matrix containing large granules. The refined flour added semolina pasta shows an open and discontinues structure due to the disruption. The addition of refined flour shows more compact structure which has low water absorption during cooking. Unswollen starch granules are also present durum wheat. Due to the presence of layered gelatinized starch absorption of water are comparatively less. Chauhan *et al*., 2017 [22] discussed about the microstructure of raw and cooked pasta. Raw pasta has visible starch granules covered with a protein matrix. Small holes are also present in it which allows the entry of water during cooking. A complex structure was formed by the covering of protein network of starch granules.

Ramya *et al*., 2014 [75] shows that the starch granules can be seen in the outer layer of freeze dried pasta. During extrusion, the starch granules are swollen and not similar in shape and size. Shreenithee *et al*., 2013 [82] show that the size of starch granules of yellow pea flour is smaller than semolina flour. The starch molecules are covered by protein can be seen in the SEM graph of yellow pea flour. A comb like structure is seen in Conchiglie pasta which has a good network because of the presence of gluten. A discontinuous and broken structure like a honey comb was observed in control vermicelli causes cooking losses and leaking of amylose. Sethi *et al*., 2020 [78] discussed an oblong shape of starch granules with a smooth surface in uncooked wheat pasta and the ingestion of rice bran into the pasta cause a breakage in the structure of protein. Madhumitha *et al*., 2011 [58], says that melting and depolymerisation of starch will take place during extrusion. The commercial durum wheat has a fibular network of coagulated protein enveloped with starch granules. The starch molecules almost come out of the network and it became clearly visible in 30% black gram containing pasta. Kamble *et al*., 2020 [52] discussed that there are racks and holes present in the uncooked pasta sample and greater absorption of water during cooking was observed due to the presence of small holes in multigrain pasta samples. The weaknesses in the structure of multigrain are the major reason of water absorption and cooking loss.

7. Colorimetry of pasta

The colour of pasta is mainly measured using colorimetry which have three colorimetrc coordinates L* indicates brightness, a* indicates redness and b* indicates yellowness (SVeC *et al*., 2008) [89]. There are different measuring procedures for checking the colorimetry of pasta. According to Biernacka *et al*., 2018 [13] Commission Internationale de l'Eclairage L*a*b* colour system is used for pasta manufacture. According to Tazrart *et al*., 2016 [90] Chroma meter is used to check the colour of pasta. L*, a*, b* are colour reading expressed using hunters lab in chromameter (odey *et al*., 2020) [68]. According to Martinez *et al*., 2012 [62], Colour score (CS) was calculated using the equation $CS = [L* + (b \times 2)]/20$.

Tazrart *et al*., 2016 [90] discussed about the colour change in pasta after the addition of broad bean. Bright yellow colour pasta is the acceptable range of pasta by customers. The addition of broad bean flour in to durum wheat pasta does not affect the colour and cooking time. There was an increase in a* value of cooked and uncooked pasta by changing colour of pasta from yellow to red colour. By increasing the addition of broad from 10-30% there was a decrease in b* value (16.5 ± 0.1 to 15.7 ± 0.1). Sobota *et al*., 2020 [84] says about the addition of vegetable concentrate into coloured pasta production. The addition of beet powder into pasta cause a decrease in L* value and an increase in a* value (dark red colour).The beet concentrate added cooked pasta cause an increase in L* value (68.87 ± 1.14), decrease in a* (7.40 ± 0.71) and increase in b* value (17.52 ± 0.73). The colour change happened in carrot was correlated with carotenoid content. Cooked Carrot added pasta increases yellow and red colour in it.

Armellini *et al*., 2018 [6] explains the effect of saffron addition in pasta. As the addition of the saffron powder increases, the L* values decreases and a* and b* value increases. The a* parameter is related to red colour. The saffron is rich in carotenoid and the pasta possesses a dark orange colour which closely related with a* parameter. The trends of a* and b* were displayed a positive values for both parameters due to saffron concentration. After cooking, saffron enriched pasta possesses a different colour than control samples because of the ability of pasta to retain its chromatic components even after the decrease of colorimetric coordinates.

Odey *et al*., 2020 [68] discussed the production of pasta from cassava roots. The cooked 60 hour fermented pasta have higher L* values (79.83 ± 1.71) followed by non-fermented cassava root pasta (78.51 ± 2.71) and 36 hour fermented cassava root pasta (76.80 ± 2.07).The brightness of the sample increases with an increase in fermentation process. The a* values of pasta also increased with an increase in period of fermentation. The non-fermented cassava root pasta have lower a* values (-5.23 ± 0.40) and the redness of pasta increased with increase in period of fermentation. The red ness was higher in the pasta which undergone 60 hour fermentation (-3.62 ± 0.33). Biernacka *et al*., 2020 [12] discussed about the addition of banana peel in to the pasta. As the addition of banana peel increases, L* values of cooked pasta decreases. After cooking, The a* value of control pasta also decreased. The a* of control pasta was lower than pasta containing banana peel and the b* value of pasta ranges from 10.55 to 12.30. The L* value of sample increased with the addition of banana peel. The control pasta having L* value of about 71.97.

Yousif *et al*., 2003 [100] explains the incorporation of bovine dry blood plasma into biscuit flour for the production of pasta. The colour of biscuit flour pasta was brownish shade where it is darker than normal pasta after the addition of dry blood plasma into it. The colour of durum wheat pasta is similar to the shade of dry blood plasma incorporated biscuit flour pasta. The pasta formulations 4.2 g/100g, 6.3g/100g and 8.4 g/100 gm dry blood pasta are more acceptable than biscuit flour. Also the biscuit flour was less acceptable comparing with pasta formulations of 2.2 g/100 gm to 8.4g/100 gm of dry blood plasma. The colour of durum wheat was very close to the colour of 2.2g/100 gm dry blood plasma containing pasta. The colour of pasta containing 2.2 gm of dry blood plasma is very different from other formulations. The durum wheat flour pasta (83.65 ± 1) and biscuit flour pasta (82.54 ± 0.4) possess higher L* values than comparing with pasta containing dry blood plasma. There was a significant decrease in L* values after the addition of Bovine samples from 80.19 ± 0.45 for 2.2 g/100gm to 77.36 ± 0.86 for 8.4 g/100 formulation. There was significant increase in a* values (1.99 ± 0.0.9 to 2.88 ± 0.22) of pasta after the addition of dry blood plasma into pasta. The L*, a*, b* values indicates the higher increase in DBP addition and the biscuit flour become darker, redder and more yellow.

Desai *et al*., 2018 [33] discussed about addition of salmon with semolina pasta. As the addition of salmon in pasta increases the lightness decreases (91.01 ± 0.08 to 88.18 ± 0.48). The Control pasta has higher lightness comparing with others (95.45 ± 0.24).The b* values increased as the concentration of salmon in pasta increases (-11.59 ± 0.66 to -9.29 ± 0.85).The control pasta also have lower redness comparing with others (-12.34 ± 0.23).Higher yellow colour (30.11 ± 0.37) was observed in control pasta and pasta containing 10% salmon powder have lower yellow colour (26.14 ± 0.63). According to Foschia *et al*., 2014 [38], dietary fibre added pasta shows low L* value than control pasta. The pasta fortified with β-glucan barley shows similarity with semolina control pastas. The pasta containing more dietary fiber have darker colour.

8. Conclusion

Pasta is an extruded product made from different cereals like wheat, oats, barley, maize, sorghum etc. Pasta is originated from Italy and it contains different micronutrients and macronutrients. It mainly contains more carbohydrates, protein and low fat. Different types of pasta are innovating nowadays and it has importance among researchers also. Food fortification can decrease the deficiency of nutrients in well-being. Single screw extruder and twin screw extruders are used for the production of pasta. The fortification of wheat with other cereals or plant and animal sources can greatly affect the nutritional content, thermal stability, colour and microstructure of pasta. The high temperature treatment of pasta can cause cooking loss. Cooked pasta always contains higher antioxidant activity, flavonoid content and total phenolic content than uncooked pasta. The gluten content always enhances the firmness and stickiness of wheat flour. But, it can be changed during heating due to hydration of starch granules. The stickiness of pasta is determined by the leaching of amylose from gelatinized starch granules. The high temperature treatment of pasta can cause millard reaction and furosine content is used to detect whether any damages were caused during thermal treatment of pasta. The microstructure of wheat pasta is always homogenous in structure and proteins are entrapped in protein starch matrix. The common wheat possess a compact and thick structure. The common wheat pasta always possess high lightness and low redness.

9. References

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