Effect of using whole meal of different grains and their mixtures on different properties of macaroni

ABSTRACT

Aims: Whole meal wheat, Barley and millet are having superior nutritional qualities and health benefits; hence they can be used for supplementation of macaroni and and its effect on physiochemical, rheological, color parameters, cooking quality, nutritional value of macaroni and sensory analysis.

Place and Duration of Study: Regional Center for Food and Feed, Agriculture Research Center, Giza, Egypt.

Methodology: Macaroni was prepared using whole meal wheat, barley, millet and composite meals mix (1) 25 % (barley and millet)+75 % wheat , mix (2) 50 % (barley and millet)+50 % wheat and mix (3) 75 % (barley and millet)+25% wheat. Proximate chemical composition, rheological, color parameters, cooking quality and sensory evaluation were measured of wheat, barley, millet and composite meals macaroni.

Results: It's indicated that increasing the level of millet replacement led to increasing the fat, ash and total fiber in the products. B-glucan content in barely represented the superiority (3.90%) as compared with other samples. Substitution of wheat meal by mixed barley and millet meal in macaroni making significantly increased in the water absorption while it significantly decreased the cooking time. Highest value of water absorption 54.60 % was found for wheat meal and lowest value 35.0% was obtained for millet. Color characteristics indicate that an increasing proportion of millet meal had signed negative effect on lightness and overall acceptability. While barley addition showed significant positive effect on lightness and overall acceptability. Sensory evaluation scores indicated non significant difference among the control and barley experimental products for overall acceptance, then mixed (1) and millet were the lowest value of overall acceptance.

Conclusion: Data concluded the possibility of producing macaroni relatively higher in fiber and β-glucan without considerable bad effects on its cooking quality and sensory properties and has many benefits for health of diabetes, high cholesterol patients and hart diseases.

Keywords: Wheat; barley; millet meal and mixed macaroni; sensory properties

1. INTRODUCTION

At present, dietary guidelines recommend an increase in the consumption of whole grain cereal products due to their role in reducing the risk of degenerative chronic diseases. Whole grains contain all parts of the grain viz., the endosperm, germ, and bran. Whole grains are rich in nutrients and photochemical with known health benefits (1) and have high concentrations of dietary fiber, resistant starch, and oligosaccharides. They are also rich in antioxidants including trace minerals and phenolic compounds and these compounds have been linked to disease prevention. Other protective compounds in whole grains include phytate, phyto-oestrogens such as lignans, plant stanols and sterols, and vitamins and minerals. Several epidemiological studies have shown that consumption of whole grain cereals is associated with reduced incidence of diabetes (2; 3), cardiovascular diseases and

certain cancers (4; 5). In order to maintain these substances in the end-products, whole grain flours and /or fortified flours are recommended for the production of health enhancing or functional foods. Traditionally, pasta products are made from wheat semolina, although more recently other cereals have been used to partially replace it (6). Common wheat flour also can be useful for precooked pasta products, but because of the low protein content, addition of high protein components such as whole grain flour may enrich the products and result in improved functional properties and quality when the right processing conditions are used. Hull-less barley being a cereal grain is suitable for use in many food products e.g. breakfast cereal pasta, and baked products. The nutritional value of whole-grain barley to be low in fat content and higher in total dietary fiber therefore has a positive health profile. In addition, the essential amino acid profile of barley protein equals, or exceeds, that of other cereal grains, especially maize and rice. Barley grains are a good source of both soluble and insoluble dietary fiber with clinically demonstrated health benefits such as attenuation of postprandial glycemic and lowered cholesterol levels. The (1→3, 1→4)-Beta-D-glucan (henceforth referred to simply as Beta-glucan) content of cereals ranges from 1% in wheat to 3–7% in oats to 5–11% in barley. Beta-glucans from barley have been found to reduce blood glucose and insulin levels with hypo-cholesterolemic effects (7). The Food and Drug Administration (FDA) has indicated that dietary intake of 3 g/day of barley β-glucan helps to decrease total cholesterol in both the serum and the low-density lipoprotein (8). Finger millet *(Eleusinecoracana)* also known as ragi is one of the important millet consumed without dehulling. It has a well-balanced amino-acid profile and is good source of methionine, cysteine and lysine. It also contains 72% carbohydrates major proportion of which is in the form of non-starchy polysaccharides and dietary fiber, which upon consumption helps in constipation and lowering of glucose level in blood. It is a rich source of vitamins viz, thiamine, riboflavin, folic acid, and niacin. Pearl millet ***(****Pennisetumtyphoids)* is an important coarse cereal grain. It has high levels of calcium, iron, zinc, lipids and a well- balance protein with high concentrations of threonine and tryptophan along with less (but adequate) leucine than other cereals (9). Millets have nutraceutical properties in the form of antioxidants which prevent deterioration of human health such as lowering blood pressure, risk of heart disease, prevention of cancer and cardiovascular diseases, diabetes, decreasing tumor cases etc. (10*)*. Millet is easily available and cheap in cost. Millet is gluten-free food. Millet can be a substitute for celiac patients respect to protein, energy, vitamins and minerals.

Bread and Pasta are the major processed cereal products that are part of the daily diets of the most people in large number of countries and especially the Mediterranean as in Egypt. While these products are low in fat and good sources of complex carbohydrates, they are usually not good sources of dietary and, in particular, soluble fiber (11). Pasta's versatility, long shelf life in dry form, availability in numerous shapes and sizes, high digestibility, good nutrition, and relatively low cost are attractive to the consumer. As people become more concerned about their health, pasta becomes more important in helping them to improve their diets. It has become more popular due to its nutritional properties and being regarded as a product with low glycemic index (12). Pasta with a mixture of durum wheat and beta-glucan enriched barley flour (BF) (60/40%, w/w) and found it to have a final content of 5% β-glucan. Quality parameters, cooking loss and dry matter did not vary substantially from the control, suggest in high potential for consumer acceptance (13). Pasta is a highly acceptable food worldwide and is generally produced from wheat semolina. The commercially produced pasta is rich in starches and protein. The addition of millet flours to the pasta will improve the dietary fiber content (14). Therefore the present study was aimed to optimize the macaroni formulations of high nutritive value and quality of macaroni by the supplementation of whole meal wheat, barley, millet and their mixed and its effect on physiochemical, rheological, color parameters, cooking quality, nutritional value of macaroni and sensory analysis.

2. MATERIAL AND METHODS

2.1 Materials

Wheat *(Triticum durum),* barley *(Hordeum distychum)* and millet *(Pennisetum Spp.)* grains cultivar was obtained from Egypt. Wheat, barley and millet which was obtained from Corp Intensification Research Department - Field Crops Research Institute - Agriculture Research Center during 2018.

2.1.1 Preparation of whole meal flours

A ten kg of wheat, barley and millet sample used in this investigation was stored at temperature 25°c and relative humidity less than 62% according to the methods described in (15). Wheat, barley and millet sample was cleaned mechanically to remove dirt, dockage, imparters and other strange grains by Carter Dockage Tester according to the methods described in (16). The extraction rate of flour sample was adjusted to recurred rate (100% extraction) which had milled by laboratory mill 3100 Perten according to the methods described in (17) for whole meal flour**.**

2.1.2 Analysis of Raw Materials

2.1.2.1 Physical properties

Cleanliness, dockage, shrunken and broken, foreign materials, total damaged kernels and total defects were separated and determined manually (hand picking). Test weight pound per bushel**,** Test weight P/B = (Kg／Hectoliter) ÷ 1.278 according to (15). A thousand kernel weights were determined by counting the kernels (wheat, barley and millet) in a 10 g sample (18). Gluten and falling number were determined to whole wheat meal, barley, millet and their mixtures according to (19).

2.1.2.2 Determination of color of raw materials and produced macaroni

Colour was evaluated by a colorimeter CR-400 (Konica Minolta, Japan) in the CIE LAB colour space: Commission International de l'Eclairage (CIE) tristimulus L* a* b* parameters were determined using colour meter (Colour Tec PCMTM Color Tec Associates, Inc., Clinton, NJ, USA), according to the method outlined in (18).

2.1.2.3 Chemical properties

Moisture, crude protein, ash, crude fiber, fat, mineral, vitamins and aflatoxin were determined to whole meal wheat, barley , millet and their mixtures according to (19) and (15). The nitrogen free extract (NFE) was calculated by difference. Beta-glucan was determined according (20).

2.1.2.4 Rheological properties

All mixtures of flours were tested by Alveograph, consistograph while amylograph was used to determine the maximum viscosity, temperature at the maximum viscosity and the transition point according to the methods described in (17) in Regional Center for Food and Feed, Agri. Res. Center, Cairo, Egypt). To determine the rheological properties of the different types of whole meal grains and their mixtures according to the methods described by (17).

2.2 Methods:

2.2.1 Whole meal pasta processing

The whole meal pasta was processed into flour, using the method of fresh pasta dough according to the methods described in Regional Center for Food and Feed, Agri. Res. Center, Cairo, Egypt (17). All macaroni was used in this formula to produce whole meal pasta by six formulas:

1-Wheat 100%
2-Barley 100%
3- Millet 100%
4-Mix1= (12.5% barley, 12.5% millet and 75% wheat)
5-Mix 2= (25.0% barley, 25.0% millet and 50% wheat)
6-Mix 3= (37.5% barley, 37.5% millet and 25% wheat)
to produce six types of macaroni.

2.2.2 Evaluation of cooking quality of produced macaroni

Cooking quality, increase in volume, cooking loss and optimal cooking time was carried out according to the method outlined in (18).

2.2.3 Sensory evaluation

The sensory characteristics of pasta were evaluated according to (21). Sensory attributes like appearance, flavor, taste, colour, mouth feeling and overall acceptability for all the samples were assessed**.**

2.2.4 Statistical analysis

Data of three replicates were determined by Duncan's multiple range test at ($P \leq 0.05$) level was used to compare between means using SAS programs (22).

3. RESULTS AND DISCUSSION

3.1 Proximate analysis for whole meal wheat, barley, millet and their mixtures

The proximate composition of the samples, including moisture, protein, fat, ash, fiber, nitrogen free extract and total caloric values is shown in Table (1) in the present study. The results revealed that the moisture content were no significant effect for both wheat, mix 1 and mix 2 meals (10.50, 10.50 and 10.20 gm/100 gm respectively).The average protein content of wheat meal and barley ranged between 13.4% - 9.8%, respectively, these agreements with work by (23). The high fat content of meal was millet and lowest value was recorded in mixture (3) 4.2% and 1.21% respectively. And (24) reported 1.58 per cent fat in wheat and 35.5 per cent fat in flaxseed, Per cent fat content of oat, maize, pearl millet and mungbean was 4.42, 4.74, 5.47 and 1.85 %, respectively**.** The ash content of meal ranged between 1.80 % to 1.06 % millet and barley respectively**,** (25) reported 1.53 % ash content of pearl millet. The ash content indicated a rough estimation of the mineral value of the product. The high fiber content was millet 8.5% and the lowest was mix 3 meals 1.30%. Our results are in conformity with (24). Nitrogen free extracts (NFE) % ranged between 65.8-77.55% for millet and mix 3, these results are lower than results by (26).The calorific value of samples was ranged between 345-363.6%. Barley had highest calorific value when compared to other treatments. Millets contain 60-70% carbohydrates, 7-11% proteins, 1.5-5% fat, and 2-7% crude fiber (10*)*. While β-glucan content in barely flour represented the superiority (3.90) as compared with its content in millet flour (0.75 mg/g) and wheat flour (0.70 mg). These results are in agreement with (27).

Table 1: proximate analysis for whole meal wheat, barley, millet and their mixtures

Analysis	Wheat	Barley	Millet	Mix 1	Mix 2	Mix 3
Moisture content %	10.5 ^{a}	7.6 ^{c}	8.7 ^{b}	10.5 ^{a}	10.2 ^{a}	8.2 ^{b}
Protein content %	13.4 ^{a}	9.8 ^{d}	11.0 ^{c}	12.1 ^{b}	11.7 ^{b}	10.6 ^{c}
Fat content %	1.43 ^{c}	1.75 ^{b}	4.2 ^{a}	1.27 ^{d}	1.24 ^{d}	1.21 ^{d}
Ash content %	1.45 ^{ab}	1.06 ^{c}	1.8 ^{a}	1.27 ^{bc}	1.22 ^{bc}	1.14 ^{bc}
Fiber content %	1.52 ^{c}	2.64 ^{b}	8.5 ^{a}	1.35 ^{c}	1.32 ^{c}	1.30 ^{c}
Nitrogen free extracts %	71.7 ^{c}	77.2 ^{a}	65.8 ^{d}	73.91 ^{b}	73.92 ^{b}	77.55 ^{a}
Total caloric values %	353.3 ^{b}	363.6 ^{a}	345.0 ^{c}	353.9 ^{b}	355.2 ^{b}	363.2 ^{a}
β-glucan	0.70 ^{e}	3.90 ^{a}	0.75 ^{e}	1.12 ^{d}	1.50 ^{c}	1.91 ^{b}

a,b,…Means with the same letter in the same row are not significantly different at ($P \leq 0.05$).

3.2 Minerals for whole meal wheat, barley, millet and their mixtures

Minerals for wheat, barley, millet meals and their mixtures were presented on Table (2). It showed that millet was the low significant effect of calcium (8.0 mg) for all samples. Pearl millet accompanying grains of other types have oxalic acid which by forming a complex, which is insoluble, with calcium results in reduction of bioavailability of this mineral (28). The concentration of calcium in pearl millet is very less and if oxalate is present then the condition will become worse. Iron value ranged between 3.19- 2.50 mg wheat and barley

respectively, millet is also a good source of other dietary minerals like manganese, phosphorus and iron (10). The high value of Magnesium (Mg) was 126.0mg on wheat meal and the lowest value was 79.0 mg barley meal. And the high values manganese and phosphorus was wheat meal 3.99 mg and 288 mg, phosphorus that plays a key role in energy synthesis in the body. The highest potassium value was wheat 363.0 mg and the lowest value was millet 195.0 mg. Selenium (Se) value in all samples ranged between 0.003 -0.071mg. Wheat meal sample was high in zinc value compared to all samples and low value was millet samples. Minerals are located in the germ; therefore, we may expect that they are not completely lost during the refining process. Pearl millet has various micronutrients which are essentially required by our body. Total content of minerals is 2.3 mg per 100 g which is more in quantity in comparison too their cereals consumed commonly. It is a rich source of potassium, B-vitamin, phosphorous, copper, magnesium, zinc, iron, manganese (29).

Table 2: Minerals for whole meal wheat, barley, millet and their mixtures

Minerals mg	Wheat	Barley	Millet	Mix 1	Mix 2	Mix 3
Calcium (Ca)	29.0 ^{a}	29.0 ^{a}	8.0 ^{b}	25.7 ^{a}	25.2 ^{a}	24.70 ^{a}
Iron (Fe)	3.19 ^{a}	2.50 ^{a}	3.0 ^{a}	2.82 ^{a}	2.77 ^{a}	2.71 ^{a}
Magnesium (Mg)	126.0 ^{a}	79.0 ^{c}	114.0 ^{b}	111.5 ^{b}	109.5 ^{b}	107.4 ^{b}
Manganese (Mn)	3.99 ^{a}	1.32 ^{b}	1.60 ^{b}	3.53 ^{a}	3.47 ^{a}	3.40 ^{a}
Phosphorus (P)	288.0 ^{a}	2.21 ^{c}	285.0 ^{a}	255.0 ^{b}	250.2 ^{b}	245.5 ^{b}
Potassium (K)	363.0 ^{a}	280.0 ^{e}	195.0 ^{f}	321.0 ^{b}	315.4 ^{c}	309.4 ^{d}
Selenium (Se)	0.071 ^{a}	0.040 ^{a}	0.003 ^{a}	0.063 ^{a}	0.062 ^{a}	0.061 ^{a}
Zinc (Zn)	2.65 ^{a}	2.13 ^{c}	1.70 ^{d}	2.35 ^{b}	2.30 ^{b}	2.26 ^{bc}

a,b,…Means with the same letter in the same row are not significantly different at (P ≤ 0.05).

3.3 Vitamins for whole meal wheat, barley, millet and their mixtures

Millets are excellent source of vitamin B. Vitamin B such as riboflavin, Niacin, pantothenic acid**,** Pyridoxine (B6), Folic Acid (B9). In Table (3**)** millet was the high level of vitamin C 2.0 % in all samples. Wheat meal was the high value of vitamin E in all samples 7.00%. Vitamin K ranged between 1.00-2.00% in all samples. Matured and dried kernels do not have vitamin C but vitamin B is present in sufficient amount in aleurone layer and the germs. Decortications used for removing hull results in reduced levels of niacin, riboflavin and thiamine to an extent of 50% in flour. In cereals, niacin is present in both bound and free form and is mainly synthesized by using tryptophan **(**30). Quantity of niacin is enough even in hulled form of millet.

Table 3: Vitamins for whole meal wheat, barley, millet and their mixtures

Vitamins %	Wheat	Barley	Millet	Mix 1	Mix 2	Mix 3
Thiamine(B1)	33.0 ^{a}	17.0 ^{c}	Non ^{d}	29.2 ^{ab}	28.7 ^{b}	28.1 ^{b}
Riboflavin(B2)	10.0 ^{d}	10.0 ^{d}	24.0 ^{a}	20.3 ^{c}	20.9 ^{bc}	21.5 ^{b}
Niacin (B3)	36.0 ^{a}	31.0 $^{b c}$	31.0 ^{bc}	31.8 ^{b}	31.3 ^{bc}	30.7 ^{c}
Pantothenic acid (B5)	19.0 ^{a}	6.0 ^{c}	17.0 ^{b}	16.8 ^{b}	16.5 ^{b}	16.2 ^{b}
Pyridoxine(B6)	23.0 ^{c}	20.0 ^{d}	29.0 ^{a}	20.4 ^{d}	24.7 ^{b}	25.2 ^{b}
Folic Acid (B9)	10.0 ^{d}	6.0 ^{e}	21.0 ^{a}	11.2 ^{c}	17.9 ^{b}	18.2 ^{b}
Vitamin C	Non ^{c}	Non ^{c}	2.0 ^{a}	0.5 ^{c}	1.1 ^{b}	1.7 ^{a}
Vitamin E	7.0 ^{a}	Non ^{e}	Non ^{e}	5.0 ^{b}	3.4 ^{c}	1.7 ^{d}
Vitamin K	2.0 ^{a}	2.0 ^{a}	1.0 ^{b}	1.85 ^{a}	1.93 ^{a}	1.96 ^{a}

a,b,…Means with the same letter in the same row are not significantly different at (P ≤ 0.05).

3.4 Mycotoxins content for wheat, barley and millet grains

Results in Table (4) show that Mycotoxin content in wheat, barley and millet grains. It can be noticed that the sample had lowest aflatoxin content before storing under detection limit (0.5

ppb) foraflatoxin, ochratoxin, zearalenone, fumonisin. More ever it can be concluded that the sample wheat, barley and millet were under detection limit (0.5ppb) of the stander Egyptian maximum (B1=10ppb and total aflatoxin =20 ppb). Aflatoxin content was valet within the safe limit 50ml/kg recommended by (31).

Table 4: Mycotoxins content for millet, wheat and barley grain

Mycotoxins		Wheat	Barley	Millet
Mycotoxins		*	*	*
Ochratoxin ppb		*	*	*
Zearalenone ppb		*	*	*
Fumonisin ppb		*	*	*
Aflatoxin	B1	*	*	*
	B2	*	*	*
	G1	*	*	*
	G2)	*	*	*
	Total	*	*	*

***=** Under detection limit (0.50ppb).

3.5 Physical properties of wheat, barley and millet kernels cultivars

Mean values of physical properties of wheat, barley and millet were presented in Table (5). It can be concluded that the test weight for all samples which ranged from 43.1 pound per bushel for millet to 60.1 pound per bushel for wheat. Percentage of shrunken and broken of wheat was (1.10%) while thin and sound of barley was highest percentage (2.80%- 95.46 %). For damage kernels which contest of heat damage and total damage, especially wheat have highest total damage kernels percentage (1.5%) while barley and millet were lowest percentage of total damage kernels (0.83%). It can be noticed that the wheat, barley and millet haven't heat damage. More over from the same table noticed that all sample are free from insect and OK odor. Results in Table (5) showed that weight per 1000 of kernels wheat, barley and millet have highest value (60.0 gm), barley 49.50gm while wheat has lowest value (33.50 gm). For addition the kernel colour in wheat sample is red whereas barley is white and millets green. These results are in agreement with thus obtained by the Egyptian stander no. 1601/1986 and it's modification on 23/4/2002 (32) has obligation that the dockage % (first separated from sample) not exceed 1%, foreign material % not exceed 1%, total damage kernels % (heat damage ,sprout damage, insect damage and mould damage kernels) not exceed than 4%. However that difference between wheat samples, all wheat samples had graded one according to (15).

Table 5: physical properties of wheat, barley and millet kernels cultivars

Parameters		Wheat	Barley	Millet
Moisture Content (M.C)%		10.4 ^{a}	10.2 ^{a}	8.70 ^{b}
Test weight (T.W) p/b		60.10 ^{a}	49.0 ^{b}	43.10 ^{c}
Broken kernels & Foreign Material (BNFM) %		0.20 ^{b}	1.0 ^{a}	0.77 ^{a}
Sh.& B.N%		1.10 ^{a}	0.33 ^{b}	0.45 ^{b}
Thin		-	2.80	-
Sound		-	95.46	-
Damage Kernels (D.K) %	Heat Damage (H.D)%	0.0	0.0	0.0
	Total Damage (T.D) %	1.50 ^{a}	0.83 ^{b}	0.83 ^{b}
Odor		Ok	Ok	Ok
Insect		Free	Free	Free
Weigh per 1000 kernels gm		33.50 ^{c}	49.50 ^{b}	60.0 ^{a}
Hardness%		61.0 ^{b}	50.0 ^{c}	75.0 ^{a}
Colour		Red	White	Green

a,b,…Means with the same letter in the same row are not significantly different at (P ≤ 0.05).

p/b= Pound per Bushel (American unit),

3.6 Physicochemical properties of whole meal wheat, barley, millet and their mixtures

The data in Table (6) showed that the highest starch damage was in barley meal (11.20%) while (mix3) meal was the lowest (2.75%). It could be noticed from Table (6) that the wet and dry gluten of control sample was 25.60% and 7.70% respectively, with a gluten index of 61.41. Upon substituting wheat meal with 25% (barley and millet meal), wet and dry gluten contents were 20.10% and 5.90% respectively, with a gluten index of 62.80, and also, increasing the level of barley and millet meal, the gluten content (either wet or dry) and the gluten index decreased. Gluten is responsible for the elasticity and extensibility characteristics of flour dough. Wet gluten reflects protein content and is a common flour specification required by end-users in the food industry. These results agree with work by (33). From same Table (6) it can be concluded that the percentage of sediment ranged from 10 to 28 ml for wheat and barley meals. The sedimentation test provides information on the protein quantity and the quality of ground wheat and flour samples. The same table reviewed that the falling number values were ranged from 240 to 512 sec., and wheat meal had the highest value (512.0 sec.) while (mix 3) meal had lower values (240.0 sec.). It can observe that addition of barley and millet at different level to wheat meal decrease the value of falling number and developed for enzyme activity of Alfa amylase and rheological properties of dough. Generally, a falling number value of 350 seconds or longer indicates low enzyme activity and very sound wheat. As the amount of enzyme activity increases, the falling number decreases. Economic European community recommended that the falling number of flour should exceed than 230 sec (34). Also, (35) for durum wheat has obligation that protein content of durum wheat not less than 10.5% and ash content not exceed than 1.3%. At the end of the Table (6) it showed that the barley had the highest value of whiteness color 32.5% and the lowest values of yellow color 14.53%, then the millet meal which is less whiteness 2.96 % and highest value of yellow color 23.32 %. Flour color often affects the color of the finished product and is therefore one of many flour specifications required by end-users. Generally speaking, bright white color flour is more desirable for many products. This result is agreement with (36).

Table 6: physicochemical properties of whole meal wheat, barley, millet and their mixtures

Parameters		Wheat	Barley	Millet	Mix 1	Mix 2	Mix 3
Starch damage %		7.00 ^{b}	11.20 ^{a}	7.05 ^{b}	4.70 ^{c}	4.75 ^{c}	2.75 ^{d}
Gluten quantity	Wet%	25.6 ^{a}	Free	Free	20.1 ^{b}	Free	Free
	Dry%	7.7 ^{a}	Free	Free	5.90 ^{b}	Free	Free
	Hydration ratio%	17.9 ^{a}	Free	Free	14.20 ^{b}	Free	Free
	Index%	61.4 ^{b}	Free	Free	62.80 ^{a}	Free	Free
Protein sediment %		10.0 ^{e}	28.0 ^{a}	25.0 ^{b}	18.00 ^{d}	20.00 ^{c}	24.00 ^{b}
Falling number sec.		512.0 ^{a}	431.0 ^{b}	254.0 ^{e}	349.0 ^{c}	290.0 ^{d}	240.0 ^{f}
flour colour %	White	11.5 ^{e}	32.7 ^{a}	2.96 ^{f}	16.24 ^{d}	19.58 ^{c}	20.30 ^{b}
	Yellow	20.63 ^{b}	14.53 ^{f}	23.32 ^{a}	18.74 ^{c}	17.40 ^{d}	16.98 ^{e}

a,b,…Means with the same letter in the same row are not significantly different at (P ≤ 0.05)
Free= free of wheat gluten.

3.7 Rheological properties of whole meal wheat, barley, millet and their mixtures

Water absorption (WA) is a parameter indicated as the amount of water needed to develop the standard dough at the peak of the curve. Consistographe parameters of the macaroni flours resulted from different grain meals and their mixtures showed that water absorption (WA %) decreased from 54.6% for the control sample made from wheat to 35.0% for millet

meal Table (7). Water absorption is considered to be an important characteristic of flour. Stronger wheat flours have the ability to absorb and retain more water as compared to weak flours. Higher water absorption is required for good bread characteristics which remain soft for a longer time. The gradual decrease in WA% was found to be due to decreasing the level of barley and millet from 25 to 75%. This decrease can be attributed to lower gluten-starch network formation which is responsible for water absorption, as the ratio of wheat in blends. Those results in Paolo with those obtained by (37) who said that the presence of damaged starch tends to increase water absorption. Obtained results could be explained with lower moisture content and higher bran content of analyzed barley and millet meal. And (38) reported that the inclusion of a higher amount of bran in the dough formulation usually resulted in increased dough water absorption due to the higher levels of pentosans present in bran. The alveograph determines the gluten strength of dough by measuring the force required to blow and break a bubble of dough. The Tenacity (P) was (156 mm H2O) for wheat to (19.0 mm H2O) for mix 2 (Table 7). So that wheat flour was the high significant effect value (15 mm, 8.60 ml) of Expandability and Swelling (G) while (mix 2) meal was the low significant effect (9.00 mm, 6.70 ml). The P/L value is high significant effect in mix 1 (14.70 %) and the low significant effect was mix 2 (6.70 ml). Baking strength (W) was the high significant effect in wheat meal (108.0 jol). W is the most widely used characteristic because it summaries all the others. The very different shapes of the curves from 'extreme' individuals indicate the great variation in dough strength and extensibility present in the core collection. Also**,** table (7) showed the transition point, maximum viscosity and temperature at maximum viscosity as measured by amylograph. The data revealed that transition point (°C) of wheat meal was 68.45°C followed by mix1 (63.91°C). The maximum viscosity was arranged in the descending order as follows: barley meal (511.40 B.U.) > wheat meal (342.10 B.U.) which in parallel with the temperature of 94.0°C and 92.0 °C, respectively. Our results are in agreement to work by (39) how reported that amylograph parameters indicated that hull-less barley had lower gelatinization temperature and higher maximum viscosity than the hull-barley as a result of the presence of beta-glucan with a higher ratio in hull-less barley. Also, (40) suggested that a reduction in maximum viscosity of hull-barley may be associated with a reduced enthalpy of starch gelatinization, and retention of the integrity of the starch granule. The reduction of maximum viscosity may also indicate reduced degree of maximum viscosity may also indicate reduced degree of starch granule swelling.

Table (7): Rheological properties of whole meal wheat, barley, millet and their mixtures

	Parameters	Wheat	Barley	Millet	Mix 1	Mix 2	Mix 3
Consist graph	Water absorption %	54.60 ^{a}	47.2 ^{d}	35.0 ^{e}	52.40 ^{b}	49.5 ^{c}	47.3 ^{d}
Alveograph test	Tenacity mmH2O (P)	156.00 ^{a}	-	-	133.00 ^{a}	19.0 ^{b}	-
	Expandability mm (L)	15.00 ^{a}	-	-	10.00 ^{ab}	9.00 ^{b}	-
	Swelling ml (G)	8.60 ^{a}	-	-	7.00 ^{b}	6.70 ^{b}	-
	Baking strength Jol (W)	108.00 ^{a}	-	-	61.00 ^{b}	9.0 ^{c}	-
	Confiiguration rate % (p/L)	10.40 ^{b}	-	-	14.78 ^{a}	1.9 ^{c}	-
Amylograph	Transition point (Cº)	68.45 ^{a}	55.21 ^{d}	45.32 ^{f}	63.91 ^{b}	59.35 ^{c}	54.82 ^{e}
	Maximum viscosity (B.U.)	342.1 ^{f}	511.4 ^{a}	501.9 ^{b}	383.2 ^{e}	424.1 ^{d}	465.4 ^{c}
	Temperature at maximum viscosity (Cº)	92 ^{a}	94 ^{a}	96 ^{a}	91 ^{a}	93 ^{a}	94 ^{a}

a,b,…Means with the same letter in the same row are not significantly different at (P ≤ 0.05).

3.8 Chemical composition of macaroni obtained from whole meal wheat, barley, millet and their mixtures

The chemical composition of macaroni produced from the different levels of wheat, barley, millet meal was reported in Table (8). The data revealed that no significant effect of the moisture content for macaroni meal. Protein content decreased from 13.10gm/100 gm for control to 9.60gm/100 gm for barley meal. These findings were in close range with those of (33). Fat content increased from 1.11gm/100 gm for wheat macaroni to 3.3gm/100 gm for millet meal. The results are in agreement with work by (41). Ash content increased from 1.00gm/100 gm for barley macaroni to 1.5 gm/100 gm for millet macaroni. The increase in ash content may be due to the higher ash content of millet meal (1.80 gm/100 gm). As for crude fiber, the content increased from1.30 gm/100 gm for wheat macaroni to 7.20 gm/100 gm for millet meal; this may be due to the high fiber content of millet compared with wheat. Total carbohydrates decreased from 74.9 (for barley) to 66.10 gm/100 gm (for millet meal). Total caloric values increased from 337.3 to 351.5 gm/100 gm for millet and barley meal, respectively. These findings were in close range with those of (33).

Table 8: Chemical composition of macaroni obtained from whole meal wheat, barley, millet and their mixtures

Chemical composition	Wheat	Barley	Millet	Mix 1	Mix 2	Mix 3
Moisture content %	12.5 a	10.8 a	11.1 a	12.1 a	11.7 a	11.3 a
Protein content %	13.1 a	9.6 c	10.8 bc	12.5 ab	11.9 ab	11.3 bc
Fat content %	1.11 b	1.5 b	3.3 a	1.43 b	1.8 b	2.1 ab
Ash content %	1.22 ab	1.0 b	1.5 a	1.22 ab	1.23 ab	1.24 ab
Fiber content %	1.3 d	2.2 cd	7.2 a	2.15 cd	3.0 bc	3.85 b
Carbohydrates %	70.77 b	74.9 a	66.1 c	70.6 b	70.37 b	70.21 b
Total caloric values%	345.47 b	351.5 a	337.3 c	345.27 b	345.28 b	344.94 b

a,b,…Means with the same letter in the same row are not significantly different at (P ≤ 0.05).

3.9 Effect of macaroni obtained from whole meal wheat, millet, barley and their mixtures on the cooking quality

Cooking performance is an important factor in a consumer's judgment of macaroni quality. Table (9) shows the quality attribute of macaroni produced from different blends of wheat, barley, millet and their mixtures flour. The data revealed that macaroni cooking time decreased from control to mix (3)10.00 to 5.5min with increased level of mixed. Addition of mixed meal to the macaroni resulted in lower cooking time for complete gelatinization of starch as compared to control. The data revealed that no difference significant in macaroni weight. Similar trend was found regarding volume. While (42) explained such trend be the high levels of total dietary fiber and β-glucan in barley and as a result increasing the water holding capacity of macaroni. The cooking loss was increased by substitution with barley (10.34 %) compared to wheat macaroni (4.35%) then after increased level of mixed. The cooking loss is an indicator of the capability of the starch-protein matrix to retain its physical integrity during cooking (43), and only values lower than 7% are acceptable for a good quality pasta (44). Generally, non-starch polysaccharide addition increased the cooking loss (45). Also,(46) explained that increased amount of barley present in the semolina matrix had disrupted the protein-starch network, causing starches to leach out during the cooking, and consequently resulting in a decrease in pasta cooking quality.

Table 9: Effect of macaroni obtained from whole meal wheat, barley, millet and their mixtures on the cooking quality

	Treatments	Cooking time (minutes)	Weight increase (%)	Volume increase (%)	Cooking loss (%)
Macaroni meal	Wheat	10.0 [a]	180 [a]	190 [a]	4.35 [d]
	Barley	7.7 [b]	196 [a]	205 [a]	10.3 [a]
	Millet	5.9 [c]	192 [a]	200 [a]	5.5 [c]
	Mix 1	6.5 [bc]	181 [a]	188 [a]	4.52 [d]
	Mix 2	6.2 [bc]	190 [a]	200 [a]	5.25 [c]
	Mix 3	5.5 [c]	192 [a]	200 [a]	8.15 [b]

a,b,…Means with the same letter in the same row are not significantly different at (P ≤ 0.05).

3.10 The change in density as affected by cooking of macaroni made from wheat, barley, millet and their mixtures

To confirm the rheological data, density of pasta was determined before and after cooking Table (10). The data revealed that no difference significant in macaroni volume before cooking, but after cooking millet was highest values 28.0 cm2 and wheat was the lowest values of volume 23.0 cm2. So that revealed that no difference significant in macaroni's weight and Density before cooking but millet macaroni was the highest value for weight of macaroni after cooking. Mix 2 was highest values of density after cooking. The results agree with work by (33). This decrease may be due to the amount of water absorbed during cooking.

Table 10: The change in density as affected by cooking of macaroni made from wheat, barley, millet and their mixtures before and after cooking

	Treatments	Volume (cm2)		Weight (gm)		Density (gm/ cm2)	
		(Before)	(After)	(Before)	(After)	(Before)	(After)
Macaroni meal	Wheat	7.25 [a]	10.0 [a]	10.01 [a]	29.08 [c]	1.38 [a]	1.26 [ab]
	Barley	7.25 [a]	7.7 [b]	10.0 [a]	30.71 [a]	1.38 [a]	1.13 [b]
	Millet	7.26 [a]	5.9 [c]	10.05 [a]	31.0 [a]	1.38 [a]	1.11 [b]
	Mix 1	7.23 [a]	6.5 [bc]	10.03 [a]	29.85 [b]	1.38 [a]	1.25 [ab]
	Mix 2	7.21 [a]	6.2 [bc]	10.01 [a]	30.02 [b]	1.38 [a]	1.33 [a]
	Mix 3	7.24 [a]	5.5 [c]	10.0 [a]	30.26 [b]	1.38 [a]	1.16 [b]

a,b,…Means with the same letter in the same colum are not significantly different at (P ≤ 0.05).

3.11 Effect of adding different whole meal wheat, barley, millet and their mixtures on color parameters of macaroni product

Color plays a major role in consumer's perception and acceptability of the product. The observed color value of cooked macaroni with different combinations of the ingredients varied from L=92, a=-0.91 and b=10.41 for wheat while for millet flour the values were 52.0, -0.51 and -5.88 for L, a and b respectively, as shown in Table (11). And in this table represents change in lightness (L*) value of macaroni with addition of barley and millet meals, both millet meals significantly (p≤0.05) decreased the lightness (L*) value of prepared macaroni samples. Addition of mixed meals macaroni significantly affected the L*a* & b* values of macaroni. As the level of mixed meal (barley and millet) increased, the lightness (L* value) and redness (a* value) decreased, but the brightness (b* value) increased, this increase may be due to presence of barley and millet which gives macaroni a yellow tint, as they are rich sources of carotenoids. This may be due to the brick red color of finger millet seed coat and grey color of pearl millet flour (47). Also (48) observed that L* value of pasta prepared from native pearl millet was lower than the pasta prepared from depigmented pearl

millet flour. This difference in color of millet flours is due to the polyphenolic pigments present in pericarp, aleuronic layer and in endosperm region (49).

Table 11: Effect of adding different whole meal wheat, barley, millet and their mixtures on color parameters of macaroni product

Treatments		Brightness "L" L*	Redness "a" a*	Yellowness "b" b*
Macaroni meal	Wheat	92.0 [a]	-0.91 [e]	10.41 [a]
	Barley	86.5 [ab]	-0.61 [bc]	8.97 [c]
	Millet	52.0 [d]	-0.51 [b]	-5.88 [d]
	Mix 1	86.31 [ab]	-0.18 [a]	9.66 [b]
	Mix 2	80.63 [bc]	-0.65 [cd]	-8.17 [e]
	Mix 3	74.94 [c]	-0.74 [d]	-8.92 [f]

a,b,c,d…Means with the same letter in the same colum are not significantly different at (P ≤ 0.05).

3.12 Sensory evaluation of macaroni meal made from wheat, barley, millet and their mixtures

Table (12) revealed that a high significant differences in appearance at wheat and barley then mix 3 macaroni (17.14, 17.0 and 16.35 %), respectively. Meanwhile, a highly significant decrease was found as a result of millet macaroni (10.30%). These results agree with work by (33). Flavor showed significant decrease in millet macaroni but all produced macaroni showed that a non-significant differences in flavor. Taste showed high significant difference at wheat macaroni then barley then mix1 (17.14, 16.28, 14.21%), respectively. The texture of macaroni was found maximum with barley + mix1 and lowest was found with millet. Color showed high significant difference at mix (2) and low significant difference in millet (8.78-5.57%). It could be noticed that the overall quality values of tested macaroni were found to be high acceptable and scores ranged between 85.19, 84.91 % for barley and control then after that mix (1) 78.29% but the lowest was for millet 51.88%. Sensory evaluation is most reliable test as it allows overall characteristics of cooked macaroni. Effect of various process parameters on overall acceptability (OAA) is indicated in Table (12). The overall acceptability of cooked macaroni within the combinations varied from 51.88 to 85.19. As shown in Table (12) OAA decreased by increasing the proportion of barley and pearl millet meals. This may be due to unattractive dark color of finger millet and grey to yellow color of millet which limits the wider acceptability of its food products.

Table 12: Sensory evaluation of macaroni meal made from wheat, barley, millet and their mixtures

Macaroni	Appearance 20%	Flavour 20%	Taste 20%	Texture 10%	Colour 10%	Mouthfeeling 20%	Overall 100%
Wheat	17.14 [a]	17.0 [a]	17.14 [a]	8.07 [b]	7.92 [c]	17.64 [b]	84.91 [a]
Barley	17.0 [a]	16.85 [a]	16.28 [b]	8.50 [a]	8.64 [ab]	17.92 [a]	85.19 [a]
Millet	10.28 [e]	10.30 [b]	10.13 [f]	5.10 [d]	5.57 [e]	10.50 [d]	51.88 [d]
Mix 1	15.78 [c]	14.35 [a]	14.21 [c]	8.39 [a]	8.60 [b]	16.96 [c]	78.29 [b]
Mix 2	15.28 [d]	14.0 [a]	12.84 [e]	8.07 [b]	8.78 [a]	17.59 [b]	76.56 [c]
Mix 3	16.35 [b]	14.07 [a]	14.07 [d]	7.82 [c]	7.28 [d]	16.82 [c]	76.36 [c]

a,b,…Means with the same letter in the same colum are not significantly different at (P ≤ 0.05).

4. CONCLUSION

From the present study, it is found that whole meal of wheat, barley and millet fortified macaroni offer a broader spectrum for people wishing to improve the nutritional quality of

their diet. Barley and Millet are highly nutritious, rich in health promoting photochemical and dietary fiber. The mixed macaroni was slightly darker in appearance. Macaroni made of mixed meal grains showed lower water absorption and higher volume. The present study showed that macaroni with good nutritional and functional properties can be obtained from barley then mix1, mix2, mix3, respectively. Mixed meal grains could be effectively utilized for high quality macaroni which will increase the whole grain consumption and likely to reduce the risk of degenerative diseases.

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