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Quality study of cooked and dried barley semolina

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ABSTRACT: *The quality of cooked and dried barley semolina (BS) has been studied. The conducted experiment reproduced four modes of preparing BS (spices, cumin, caraway and vegetables) usually consumed in Morocco. These preparations were divided into two lots that have been cooked in boiling water "Belboula" and steam "Couscous". All have been dried at 85 ° C for 1 hour 30 to 2 hours to decrease the moisture content to 12.5%. The finished products have been subsequently packaged, stored at room temperature and submitted to physico-chemical, technological and microbiological analysis.*

An increase in ash and decrease in carbohydrate contents have been observed, particularly for belboula. The cooking steam has preserved the granular aspect of BS. Cooked in boiling water, BS particles have taken the form of flat flakes. The bulk density (g/cm^3*), optimum cooking time* (min) and *swelling index were* found to be *0.59, 13.67, 2.04 for couscous and 0.35, 12.33 and 1.86 for belboula. Regarding microbiological analysis, the experimental outcome showed good hygienic quality.*

Also, statistical analysis showed that the effect of cooking method was very highly significant (α = 0.01%) on the bulk density, the swelling index and the particle size.

Keywords: *barley, semolina, couscous, cooking, quality.*

I. Introduction

Historically speaking, barley (*Hordeum vulgare L.)* has been an important food source in many parts of the world [1, 2, 3]. It was first presumably used as human food but evolved primarily into a feed, malting and brewing grain due in part to the rise in prominence of wheat and rice. In recent times, about two-thirds of the barley crop has been used for feed, one-third for malting and about 2% for human food.

Barley lost its favor as a food grain primarily due to the improved conditions of the farming classes, growth, and development of the wheat industry.

Wheat bread and wheat-based breakfast cereal products have replaced much of the bakery markets for rye, oats and barley because of texture, taste, appearance and increased availability.

However, with increasing consumer knowledge about the health benefits provided by soluble dietary fiber and other whole-grain constituents, barley food have a good chance of regaining an important place in the human diet [2].

The major advantage of incorporating barley into various food products and their consumption stems from barley's potential health benefits. The effectiveness of barley ß-glucans in barley food products in lowering blood cholesterol and glycemic index has been reported in numerous publications and is widely accepted [4, 5, 6, 7, 8, 9,10]. Barley is a rich source of tocols, including tocopherols and tocotrienols, which are known to reduce serum LDL cholesterol through their antioxidant action [11, 12]. The recent approval of soluble barley ß-glucan health claims by the Food and Drug Administration of the USA for lowering blood cholesterol level could further boost food product development from barley and consumer interest in eating these food products.

For food uses, barley grain is first abraded to produce pot or pearled barley, and may be further processed to grits, flakes and flour [13]. Pearled barley, grits or flour have been used in the preparation of many traditional dishes in Russia, Poland, Tibet, Japan and India [1]. Pearled barley is used as a rice substitute and for the production of soy paste and soy sauce in Korea [3]. In Western countries, pearled barley, whole, flaked, or ground, is used in breakfast cereals, stews, soups, porridge, bakery flour blends and baby food [14].

In Middle Eastern and North African countries, barley is pearled and ground, and used in soups, flat bread and porridge [14]. In Morocco, barley grains, after milling, come in many forms and are used for various purposes. Barley flour (BF) is used alone or blended with common wheat flour for bread-making. While barley semolina (BS) can be used for the production of couscous, porridge "*Belboula* or D*chicha*", and other dishes [13].

However, the quality requirements of barley for food use have not been well established, making it difficult for food manufacturers to assess the quality of finished products or to select raw materials suitable for use in specific food products. Accordingly, in contrast to wheat, there has been little improvement in food processing and product development of barley.

To revalue this cereal for human consumption, this study aimed to investigate the quality of cooked and dried BS. BS was cooked in two different ways. The first one was steam cooking to produce "barley couscous". The other one consisted in semolina cooking in boiling water "Belboula".

The quality assessment was based on the criteria usually used for similar products such as couscous and pasta: composition analysis, particle size, bulk density, cooking time and swelling index [15, 16, 17]. Moreover a monitoring of the microbial flora was carried out during 6 months of storage.

II. Materials and Methods

Plant material

BS (Image 1) was purchased from a granary in Rabat city commonly called "Rahba". The ingredients used for the preparation (iodized salt, pepper, ginger**,** cumin seeds, caraway seeds, fresh tomato and onion, red pepper, parsley and cilantro) were provided from sales points of Rabat city. Tap water was used for hydratation and cooking.

BS was sieved and sorted manually to remove the remaining flour and any impurities. It was then rinsed with a jet of water and dewatered. BS used for steam cooking has been soaked in water and left to stand for 5 minutes before cooking. The cumin and caraway seeds were also sorted, rinsed with water and then drained. Vegetables, peeled onions, red pepper and tomatoes were washed and cut into cubes. After these preliminary steps, four formulations were prepared (Table 1).

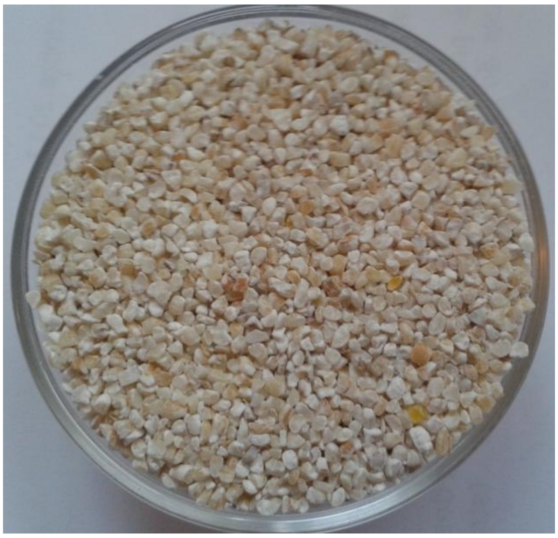

Image 1: Barley semolina

Table 1: Formulation of BS preparations

Ingredient (g)	**Boiling water cooking**				**Steam cooking**			
	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4
BS	98,6%	98,4%	98,4%	97,6%	98,6%	98,4%	98,4%	97,6%
Salt	0,8%	0,8%	0,8%	0,8%	0,8%	0,8%	0,8%	0,8%
Pepper	0,4%	-	-	-	0,4%	-	-	-
Ginger	0,2%	-	-	-	0,2%	-	-	-
Cumin seeds	-	0,8%	-	-	-	0,8%	-	-
Caraway seeds	-	-	0,8%	-	-	-	0,8%	-
Tomato, onion, red pepper, parsley, cilantro.	-	-	-	1,6%	-	-	-	1,6%

Equipment used

- Electric aerated dryer (hot air flow =4.58 m^3 / h, speed = 0.8 m / s);
- Oven drying ED 53 ED Series BINDER to a maximum temperature of 300 °C and a built-in timer. It is also provided with a fan which ensures the convection hot air **;**
- Electronic Balance Explorer Pro EP2102 with a capacity of 2100 g and an accuracy of 0.01 g;
- Moisture analyzer MX-50;
- Conventional cooking equipment (gas oven, pot, couscous-cooker, Screens, containers, wooden dish called "*guessâa*").

Diagram manufacturing

Samples of BS were prepared, cooked and dried according to the diagram shown in Fig 1. Cooking operation was conducted in two different modes: boiling and steaming. The optimum cooking time has been previously determined. For preparations cooked in boiling water, the optimal cooking time has been exceeded to ensure the removal of water by evaporation. Then, obtained products were dried to reduce moisture content to a maximum value of 12.5%. To do this, a hot aerated dryer was used. Semolina was distributed on racks and then introduced for drying. To prevent drops of the product through the openings of the trays, a cotton

fabric was used. The product was spread on a thin layer to avoid clogging of the openings of the tray and providing a flow of hot air out of the dryer.
The dryer was previously settled to a temperature of 85 °C. Continuous monitoring of weight loss has been achieved. After cooling, the dried products were labeled and packed in plastic bags of 20 g each.

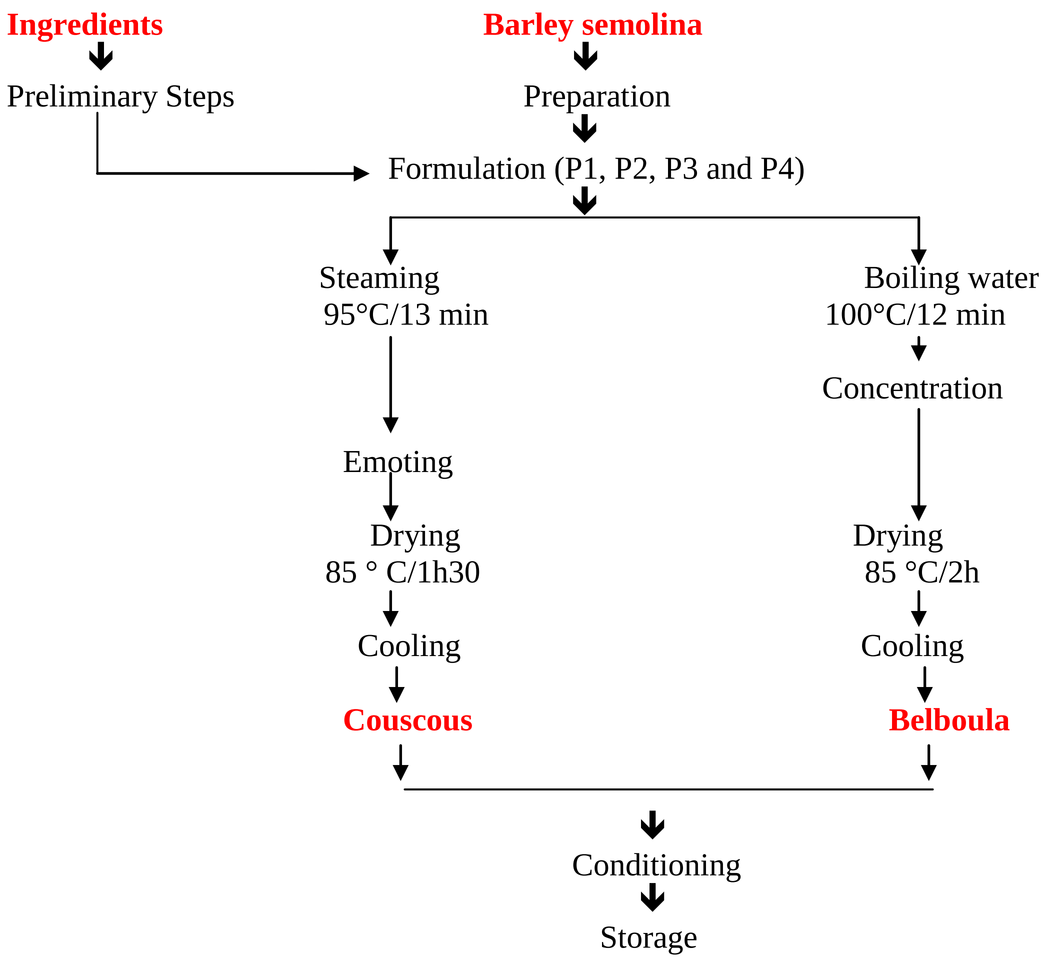

Figure 1: Diagram of cooked and dried BS manufacturing

Chemical analysis
Moisture of BS and finished products was measured according to the method of Moroccan standard NM 08.1.202 [18]. As for the monitoring of moisture variation during the drying process, a moisture analyzer (Moisture analyzer MX-50) for rapid determination was used.
Ash content was determined according to the method published by Moroccan standard NM 08.1.211 using muffle furnace (model Tipoforno ZA No. 18203 Gef Ran 1001) [19].
Protein content: the Kjeldahl method as published by the Moroccan standard NM 08.1.206 [16] was used (protein factor was N × 6.25) [20].
Lipid content was determined according to the method published by French Standard NF V03-713 / NF EN ISO 11085) [21].
Total carbohydrates were calculated by difference according to Pearson (1976) [22].

Physical analysis:
Particle size of BS, bebloula and couscous was determined according to the method published by the Moroccan Standard NM 08.1.224 using a rotatory tapping sieve shaker (Chopin Instruments, Rotachoc Type) [23]. A test sample of 100-200 g (±0,01g) was sifted using superposed sieves with different sizes of sieve holes (2000, 1250, 850, 630, 500 and 200 microns) during 10 min. Granulation curve was drawn by calculating the cumulative percent of product held on each screen.
Bulk density: A calibrated cylinder of 100 ml was used to determine the volume occupied by 25 ± 0.01 g. Bulk density was expressed in g/cm^3.

Technological analysis

Cooking time (CT): Preparations of BS were cooked in boiling water and steam. For boiling water, CT was measured according to the method published by ICARDA [24]. CT was measured from the starting time of cooking until at least 90% of the grains were cooked and ready to eat. Concerning steam cooking, preliminary tests were conducted to determine the optimal cooking time to apply for all preparations. The procedure of CT determination was conducted according to chart shown in Fig 2. To perform this test, about two litres of tap water were previously boiled in the pot of steam-cooker. Cleaned and moisturized BS was placed in the steam-cooker to be cooked at low fire. Hence, the time for cooking is to be registered. Two different times were noted:

- The first time corresponding to the minimum clearance of the first vapor stream from the surface of BS.
- The second one is called optimum time. In this case, the vapor stream emerges from the entire surface of the granules and BS changes color. At this time, the granules of semolina barley are individualized and become soft.

The test is repeated twice. CT represents the sum of both optimal time determined during the first and second cooking.

Swelling Index (SI): SI was measured according to the method published by the Moroccan standard NM 08.1.255 [25]. In calibrated cylinder (internal diameter between 35 and 42 mm) of 250 ml (±2 ml), 50 g of dry product was introduced to measure the volume occupied: V_1 (±2 ml). The cylinder was emptied and the sample was preserved carefully. Afterwards, this cylinder was filled in with 200 ml (± 1 ml) of tap water at 20 ± 2 °C and then the sample was poured quickly. The mixture was stirred two or three times to ensure that no particle floats. After 30 min ± 1 min, the volume V_2 (±2 ml) occupied by the product in the cylinder was noted. **Swelling Index (**SI) is given according the following equation: $\mathbf{SI = V_2 / V_1}$.


Image 2a: Semolina hydratation

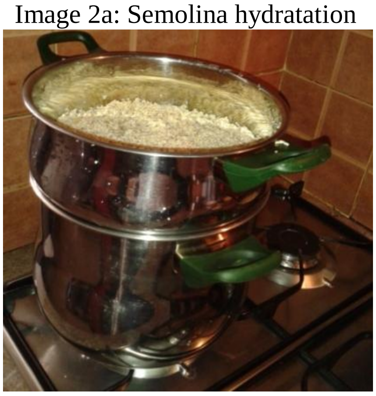
Image 2b: Steaming


Image 2c: Emoting

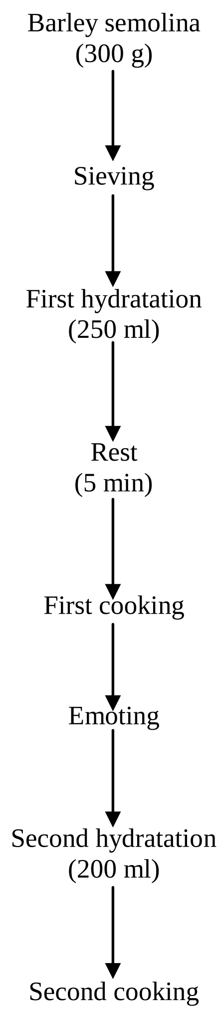

Figure 2: Determination of BS cooking time

Microbiological analysis

Total aerobic mesophilic flora (**FAMT**), yeast and moulds were carried out during 6 months of storage. Sampling was realized each 30 days.

FAMT: It is a good indicator of contamination which was enumerated on Plat Count Agar (PCA). All plates were incubated at 30°C for 72 h, based on the standard test [26].

Moulds and yeasts were counted on Potato Dextrose Agar (PDA), after incubation at room temperature for 5 days [27].

III. Results and Discussion

Raw material characterization

Results of BS composition and particle size are reported in Table 2 and Fig 3. Moisture and ash content were found to be 10.85 and 1.01(% dry matter basis) respectively. The moisture value is consistent with that found for barley flour [28]. ElYamlahi and *al.* (2013) [13] reported that barley in Morocco is milled without tempering.

However, for ash, it is much lower than that found in flour. Unlike those of flour, barley semolina particles come from the endosperm of the grain known for its low mineral content. It is generally accepted that the mineral content increases from the inside to the outside of the grain. Hoseney (1986) [29] reported that the aleurone layer contains most of the minerals with nearly 60% of the total. Ash content is a criterion for assessing the purity of the flour. Feillet *et al*., (2000) [30] reported that the degree of purification of the flour has a pronounced effect on the browning of pasta: the more semolina is contaminated with the peripheral parts of the grain, the more brown and dull pasta is.

Table 2: BS composition

Criteria	Average
Moisture (%)	10.85
Ash (% dry matter basis)	1.01
Proteins (Nx6, 25) (% dry matter basis)	9.48
Fat (% dry matter basis)	1.46
Carbohydrates (% dry matter basis)	88.06

As for the other tests, BS was found to contain protein 9.48, fat 1.46 and carbohydrate 88.06% (% dry matter basis). These findings corroborate the results of Pedersen and Eggum (1983) [31] and Hegedus et *al*. (1985) [32]. Similarly, Bhatty (1987) [33] reported that barley flour, obtained in a mill lab, contains the average values of 9.9, 1.1 and 14.9% respectively for moisture, ash and proteins contents. Compared to the soft wheat flour, the barley flour has substantially the same clarity, similar protein but a higher rate of ash.

As for BS particle size, an average of 98% of the BS particles remained over a 630 microns screen and about 10% went through a 500 microns sieve (Fig 3). Compared to the size ranges set by the Moroccan standard NM 08.1.232 [34], the product analyzed may be classified as coarse semolina.

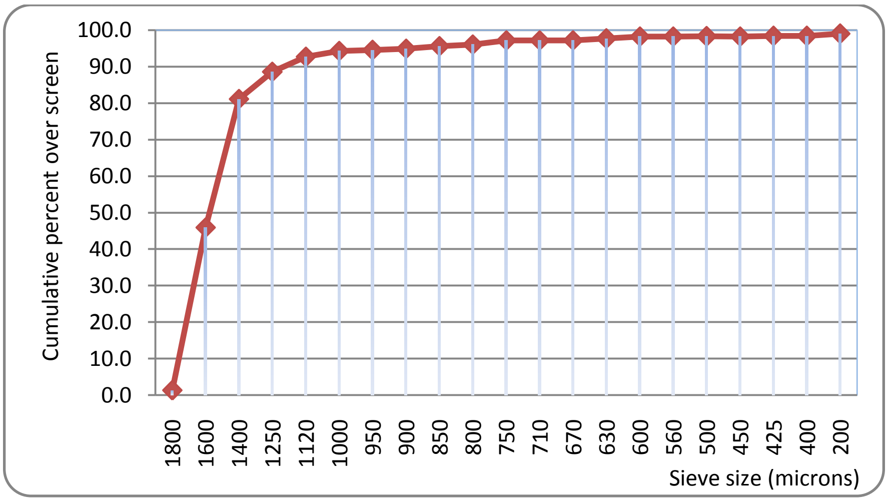

Figure 3: BS granulation curve

The particle size distribution affects the absorption properties [35]. In the same vein, Hebrard et *al.* (2003) [36] reported that the particle size of the semolina influences their sorption kinetics. The finer the particles are, the faster their kinetic sorption is. Aluka *et al*., (1985) [37] reported that the semolina particle size plays a very important role in the determination of the technological and culinary quality of a consumer product. Granules of diameter superior to 500 microns lead to low water absorption. Likewise, granules less than 200 microns (flour) are very sensitive to the thermal effect, which leads to a gluten denaturation and other proteins by coagulation during drying. The product may lose its consistency at cooking in water.

For good performance during technological operations of cooking and drying, it is recommended not to exceed 10% for the dispersion of the particles around the median value.

BS couscous and belboula preparations

- ***Composition analysis***

Results analysis of composition of belboula and couscous are shown in Table 3. The finished products are illustrated in image 3. The analysis of these results reveals the presence of significant variations between raw material (BS), belbloua and couscous. BS processing resulted in an increase of ash and reduction of carbohydrate contents.

Table 3: Composition of couscous and belbloua

Product	**Preparation**	**Way of cooking**	**Moisture (%)**	**Content (%** dry matter basis)				
				Ash	**Protein** (Nx6.25)	**Fat**	**Carbohydrates**	**Sum**
Belboula	P1	Boiling	10.15	3.28	9.07	2.46	85.19	100.00
Belboula	P2	Boiling	9.80	2.27	9.43	2.25	86.06	100.00
Belboula	P3	Boiling	10.15	2.07	10.71	1.92	85.31	100.00
Belboula	P4	Boiling	10.20	3.18	8.94	1.77	86.11	100.00
Couscous	P1	Steaming	11.60	1.64	9.78	2.69	85.89	100.00
Couscous	P2	Steaming	12.10	1.50	9.61	2.65	86.25	100.00
Couscous	P3	Steaming	9.30	1.87	9.59	1.65	86.88	100.00
Couscous	P4	Steaming	10.20	2.18	9.69	1.31	86.82	100.00

- *Moisture*

Moisture value was ranged from 9.30 to 12.10% (Table 3). Moisture is an important factor because it determines the aptitude of a product to conservation and consequently its shelf life. These values comply with the limit fixed by *Codex Alimentarius* standard [38]. To control the final moisture preparations during drying process, weight and moisture were monitored at regular time intervals. The Fig 4 shows a comparison of the evolution of the weight loss during drying process for the two cooking modes. The average drying time was set to 1h30 for couscous and 2h for belboula.

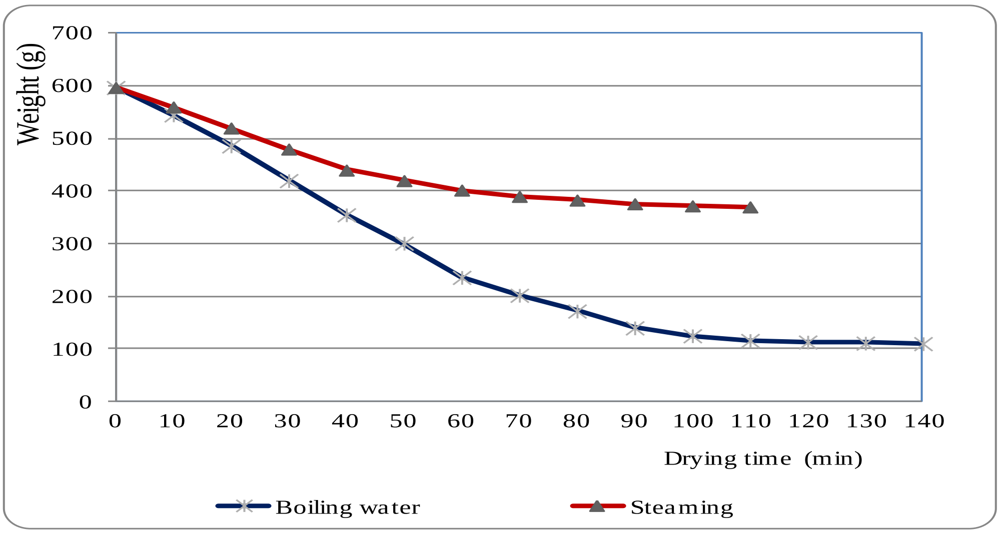

Figure 4: Drying average curves for BS preparations

- **Ash content**

A significant increase of ash content was observed for all BS preparations. This result is consistent with the work carried out by Guezlane et *al.* (1986) [39], who highlighted that a net increase of ash rate was observed for couscous as opposed to semolina from which it was made.

However, the increase varied depending on the cooking way. Belboula preparations have an ash content ranging from 2.07 to 3.28 (% dry matter basis) while the rate of ash in steamed preparations has registered low. A minimum of 1.50 and a maximum of 2.18 (% dry matter basis) were noted.

The increase in ash content, thus observed, is mainly due to the minerals provided by the added ingredients, including salt and water in the case of the cooking water. It is observed that there is a concentration of salt content in the finished product after evaporation of water by drying.

The difference between the two cooking modes is explained by the fact that the mineral elements of the cooking water were finally found in the residual mass of finished products. Yet, statistical analysis showed no significant effect of the preparation and cooking way on the ash rate.

- **Protein content**

The protein content of all BS preparations varied between 8.94 and 10.71% (dry basis) (Table 3). These results were substantially similar to those found for initial BS. The importance of protein for quality cereal products is well established.

According to Quaglia (1988) [40], the protein is an important criterion to describe the couscous quality. Studies conducted by D'Egidio *et al*. (1990) [41] and Novaro *et al*. (1993) [42] showed that the protein and the gluten contents are the most important parameters to describe the cooking quality of pasta. The wheat proteins and despite their relatively low rate would be responsible for 30-40% of the variability of couscous cooking quality [43]. Moreover, statistical analysis showed no significant effect of the preparation and cooking way on the protein content.

- **Lipids content**

Lipids of grains play an important role in the expression of baked goods quality. Ounane *et al*. (2006) [44] reported that the cooking quality of couscous is partially related to the content and composition of lipids. BS preparations were found to contain an average of 2.08 (%dry matter basis). As it was indicated for BS (Table 1), lipids are little present in barley grains (about 2-3%). Lipids are particularly found in aleuronic cells and scutelum [45]. Barley has a lower fat content in comparison with maize, sorghum and oat. However, lipids which are minor components of semolina have a significant effect on the quality of grain products, including couscous. Making couscous from defatted semolina leads to discoloration, sticky increasing and reduction of hydration capacity [44]. Several studies have shown the effect of lipids in pasta making which are essentially involved in the color characteristics and the pasta cooking [46]. Statistical analysis showed no significant effect of the preparation and cooking way on the lipids content.

- **Carbohydrates content**

Carbohydrates ranged from 85.19 to 86.88 (% dry matter basis). BS processing led to decrease in carbohydrate content. It was significantly lower than the initial content (88.06% db)**.** The values obtained from belboula preparations (mean = 85.67% db) were lower than those of steamed ones (mean = 86.46% db). The barley Carbohydrates consist largely of starch which is soluble in water.
The reduction in carbohydrates, observed particularly for belboula samples may be due to the starch solubilization. Similar to the parameters discussed above, statistical analysis showed no significant effect of the modes of presentation and cooking on the carbohydrates content.

Physical analysis:

- ***Couscous and belboula particle size***

The results of particle size distribution are shown in Fig 5 and 6. A granulation curve is an illustration of the distribution of the particle size for a ground product [47]. Particle size is an important test for predicting quality characteristics of couscous. In Morocco, industrial couscous is generally packaged according to its granulometry (fine, medium and coarse). Couscous granulometry must range from 630 to 2000 microns with a tolerance of 6% [38]. Therefore, the agglomeration of BS particles is an important stage in couscous manufacturing which contributes to the final quality of the end products.

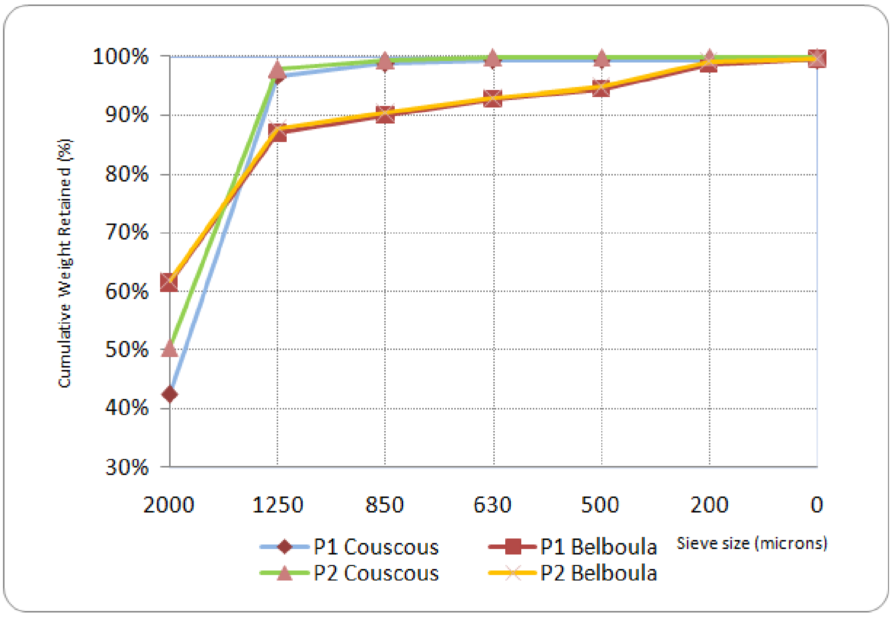

Figure 5: Granulation curve of belboula and couscous (P1 & P2)

The curves (Fig. 5 & 6) show that approximately 98 % of couscous particles remained over a 1250 microns sieve against 86 % for belboula. The average diameter (D_{50}) of couscous was 1267 microns while that of belboula was 1272 microns. The dispersion of particle size for belboula was relatively important compared with that of couscous.

The retained weight average rate for the sieve of 2000 microns was 59 and 52 % for couscous and belboula respectively.

These values exceed the tolerance (6 %) admitted by *Codex Alimentarius* Standard [39]. This exceeding may be due to the particle size of the initial BS (coarse semolina) and to technological operations of manufacturing which caused particles agglomeration.

As for couscous P4, the retained weight over 2000 microns sieve was more important. It reached 76 %. This would probably be due to the pieces of vegetables ingredients. They blocked the holes of the top sieve (2000 microns) and prevented particles passage.

As for the sieve of 630 microns, the passed weight did not exceed the tolerance fixed by *Codex Alimentarius* Standard for all the samples [38]. The obtained values ranged between 0 and 3 %.

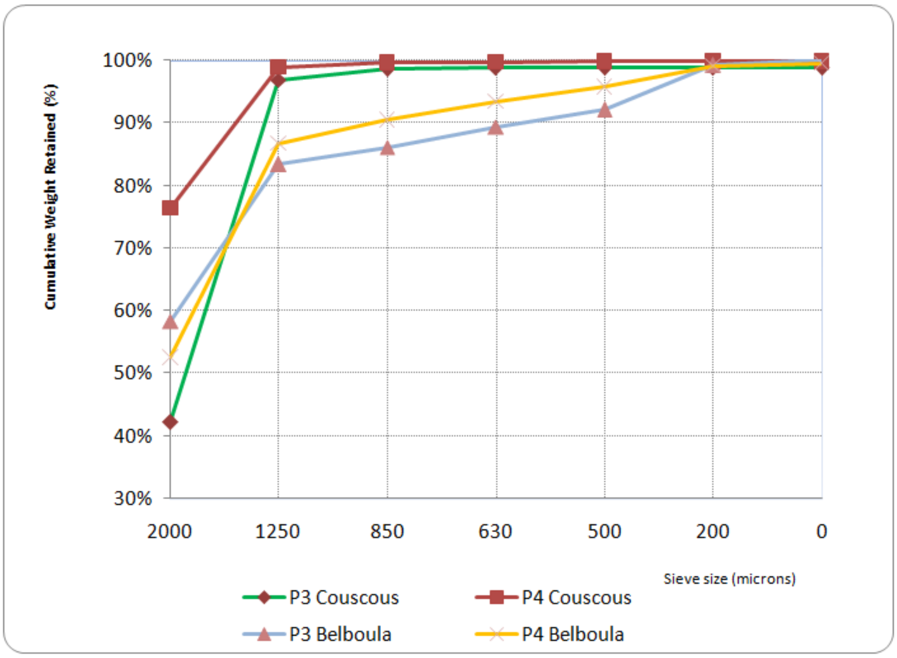

Figure 6: Granulation curve of belboula and couscous (P3 & P4)

The cooking mode had a very highly significant effect on the particle size of barley cooked semolina except for 850 microns sieve (table 4).
These results reflected the condition of couscous and belboula without any classification. It should be noted that couscous produced at the industrial level must be classified by sieving before packaging. The fine and big particles are recycled.

Table 4: Cooking and preparation effect on couscous and belboula preparations

Sieve size (microns)	Factor Preparation	Factor Cooking	Factor Interaction
2000	-	+++	-
1250	-	+++	+
850	-	-	-
630	-	+	-
500	-	+++	-
200	-	+++	-
0	-	+++	-

Legend: +: significatif, ++: highly significant, +++: very highly significant, - : not significant

- **Bulk density**

The average bulk density was found to be (g/cm^3) semolina 0.62, belboula 0.35 and couscous 0.59 (Fig 7). These values were found to be comparable to those reported by Adebayo et *al*. (2013) [48] for wheat flour (0.87 g/cm^3) and maize flour (0.98 g/cm^3). Heat processing reduced the bulk density by 77% for belboula and 5% for couscous. The particles obtained in case of boiling cooking are flakes-shape. Those obtained by steaming had preserved their granular aspect (Image 3).

Image 3a: Belboula P1

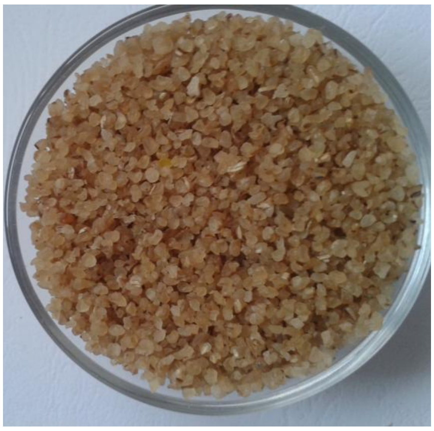

Image 3b: Couscous P_1

Image 3c: Belboula P2

Image 3d: Couscous P2

Image 3e: Belboula P3

Image 3f: Couscous P3

Image 3g: Belboula P4

Image 3h: Couscous P4

The variance analysis showed that the cooking mode had a very highly significant effect (α = 0.1%) on the bulk density of barley dried preparations, but the formulation type has no significant effect. The interaction between the two factors was significant (α = 5%).

The difference observed for bulk density between couscous and belboula is due to the particles form. With a form of flakes, the intergranular space is more important. This resulted in a decrease in density. The cooking method seemed to be the cause of this difference. Cooking in boiling water caused dissolution of the BS constituents, particularly starch. This dissolution caused the appearance of sticky aspect giving flakes shape to belboula particles.

These results corroborate with the work of Collonna and Rouau (1986) [49]. The authors reported that starch is altered by hydrothermic treatment. When the starch grains are subjected to a treatment in an aqueous solution, they swell by absorbing water, while a fraction of the solution pass through the channels mainly by amylose.

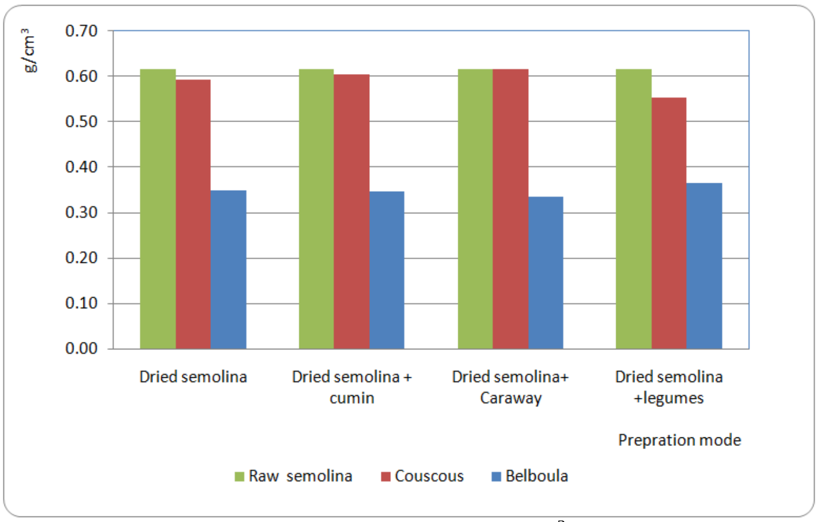

Figure 7: Bulk density (g / cm^3)

- **Cooking time (CT)**

Results of CT determination for belboula and couscous are shown in Fig 8. CT was determined to predict the time required for cooking. Average CT was found to be, boiling water 12.33 min and steam 13.67 min.
Statistical analysis showed no significant effect of cooking method on the cooking time. The time performed in the case of boiling has been exceeded to promote the evaporation of water and the concentration of the product.
Cooking of cereal products has the objective to gelatinize starch to make it hydrophilic, and to change the textural appearance of the products so as to give them the desired organoleptic characteristics.

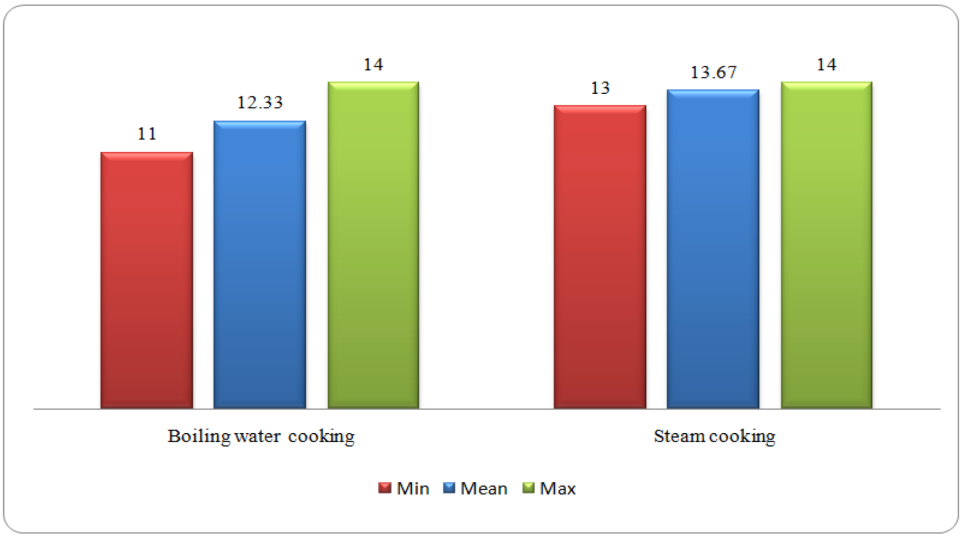

Figure 8: Optimal time (in minutes) cooking of BS

Cooking in boiling water took less time than that achieved by steaming. According to Adrian and Frangne (1987) [50], the intensity of gelatinization of starch is proportional to the volume of water, temperature, duration of treatment and all cooking methods.

Cooking cereal products, three times (minimal, optimal and maximal) can be determined. These values correspond respectively to time from which the starch is gelatinized, the time required to give to the cooked dough the sought texture and the time beyond of which products split in the cooking water.
Exceeding optimum cooking time in boiling is responsible for the final obtained aspect (flakes shape). Boudreau et *al.* (1992) [51] reported that cooking quality of couscous is appreciated by its disintegration degree and its resistance to cooking as reflected by the surface that should be non-sticky.

Barnes et al. 1981[52] reported the formation of protein-starch bonds during the hydrothermal treatment. Protein-carbohydrate matrix prevents amylose starch to migrate to the surface of couscous during cooking. The aspect flakes obtained for the case of cooking in water would be the result of amylose diffusion from the semolina surface which is responsible for particle disintegration.

- **Swelling Index (SI)**

Average SI was found to be belboula 1.86 and couscous 2.04 (Table 5). Statistical analysis showed that the cooking mode has a very highly significant effect (α = 0.1%) on the SI of dried barley preparations but formulation has no significant effect. Interaction between the two factors was significant (α = 5%).
Swelling phenomenon results from the absorption of water by semolina constituents. In the present conditions, the constituents of couscous seem to absorb more water and swell to a greater level than those observed for belboula. Steaming helped giving the BS best culinary properties. This could be explained by the presence of disintegrated particles in belboula preparations. In reality, couscous swells during steam cooking operation before consumption. It occurs as a result of combined heat treatment and steam absorption operations.

Table 5: Swelling index results for barley dried preparations

Test	Belboula				Couscous			
	P1	P2	P3	P4	P1	P2	P3	P4
Min	1,90	1,81	1,78	1,78	2,00	2,00	2,00	1,80
Max	1,91	1,90	1,84	1,92	2,30	2,20	2,20	1,90
Mean	1,91	1,90	1,84	1,92	2,30	2,20	2,20	1,90

Compared to durum couscous, high values of SI are indicative of a high quality product [16]. According to Debbouz and Donnelly (1996) [53], the ability of couscous to absorb quickly sauce and maintain its firmness is considered as an indicator of good quality.
For durum wheat couscous, SI must be greater than 2.2 [54].The results found in our study are lower. This could be explained by the content of gluten which is naturally higher for durum wheat. Boudreau and Menard (1992) [55] reported positive correlation between quality, protein content, the absorption of water and the improvement of cooking quality.

Microbiological analysis
The microbiological analysis carried out on the belboula and couscous samples were aerobic mesophilic flora, yeast and moulds. Table 6 shows the results of microorganism's counts.

Table 6: Results of microorganism's counts

Microorganism	Date of analysis	Belboula				Couscous			
		P1	P2	P3	P4	P1	P2	P3	P4
yeast and moulds /g	+30 d	< 10^1	< 10^1	< 10^1	< 10^1	< 10^1	< 10^1	< 10^1	< 10^1
	+60 d	< 10^1	< 10^1	< 10^1	< 10^1	$5.1x10^1$	$1.5x10^2$	< 10^1	< 10^1
	+90 dj	< 10^1	$2x10^2$	< 10^1	$2x10^2$	$7.5x10^1$	$3x10^2$	$1x10^1$	< 10^1
	+120 d	< 10^1	< 10	< 10^1	< 10^1	$6.1x10^1$	< 10^1	$4x10^1$	< 10^1
	+150 d	< 10^1	< 10	< 10^1	< 10^1	$2x10^1$	< 10^1	< 10^1	< 10^1
	+180 d	< 10^1	< 10	< 10^1	< 10^1	$5x10^1$	< 10^1	$1x10^1$	< 10^1
TMAF /g	+30 d	< 10^1	$2.4x10^4$	$1.2x10^4$	4.10^3	$2x10^2$	$2.5x10^2$	$1x10^1$	$1.2x10^2$
	+60 d	$6x10^3$	$2x10^3$	$1.4x10^5$	2.10^3	$6.9x10^4$	$4x10^1$	$1x10^1$	$1x10^1$
	+90 d	$6x10^3$	$2x10^3$	$1.4x10^5$	2.10^3	$6x10^4$	$3x10^1$	< 10^1	$2x10^1$
	+120 d	$3x10^1$	$1x10^2$	$2x10^1$	1.10^3	$3x10^4$	< 10^1	$5.0x10^4$	< 10^1
	+150 d	$2x10^1$	$5x10^2$	$3x10^2$	4.10^3	$7x10^4$	$3x10^1$	< 10^1	$1x10^1$
	+180 d	$6x10^1$	$2x10^3$	$5x10^2$	2.10^3	$3x10^4$	$4x10^1$	$1x10^1$	< 10^1

Microbiological analysis results of this study showed that the count of yeast and moulds did not exceed $3x10^2$ cfu / g. This value was observed for couscous P2 after 90 days of storage. However, it is not a sign of multiplication because the samples analyzed later (+120, +150 and +180 days of storage) were free of such microorganisms (< 10^1 cfu/g). According to international standard, maximum permissible range for total yeast and mould count is 10^2-10^3 cfu /g [56]. Yeasts and moulds are very important within food microbiology as they can create both positive and negative effects. Thus, they have the ability to survive and grow at low pH, low water activity and in the presence of some common chemical preservatives [57].

As for TMAF, the results showed that the count during 6 months storage was less than the range of 10^6 cfu/g fixed by Moroccan regulations [58]. The count varied from $1x10^1$ to $1.4x10^5$cfu/g. This type of micro-organisms gives information about the hygienic quality of analyzed food.

TMAF count showed that the microbial load varies from one preparation to another and according to cooking methods. Belbloula samples contained a relatively high load. The maximum range ($1.4.10^5$ cfu/g) was observed for belboula P3 samples analyzed after 60 and 90 days of storage.

Regarding these results, belboula and couscous preparations can be classified as good hygienic quality. This result could be justified by several factors: i) the manufactured products are characterized by low water activity (moisture <12.5%), ii) grain products are not favorable substrates for microorganism's growth iii), good hygiene practices have been observed throughout the stages of manufacturing iv) products have been stored away from heat and moisture.

IV. Conclusion

In conclusion, the results of this study highlighted the effect of the mode of cooking on the quality of dried barley semolina. It lead to significant differences in physico-chemical and technological properties of dried barley semolina preparations.

The results clearly reflected an increase in ash and decrease in carbohydrate contents of final products, particularly for belboula. Cooking mode influenced the particle form of finished products and their ability of rehydration. The steaming helped preserve the granular aspect of semolina as opposed to that of flat flakes out of boiling.

The manufacturing diagram studied in this work could be reproduced at the industrial scale. For belboula manufacturing, it‘s recommended to concentrate the product under vacuum.

Thanks to the health and nutritional benefits of barley products, cooked and dried barely semolina would best meet increasing demand beneficial to human health products.

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