The Technological Quality of Barley Lines Selected from the First Cycle of Participatory Breeding in Algeria

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Abstract

This paper aims at investigating the technological quality of barley lines selected from the first cycle of participatory plant breeding (PPB) conducted in Algeria, and compared them with two varieties widely grown in Algeria (Saida183 and Rihane-03). Several physicochemical and technological parameters were evaluated: thousand kernel weight (TKW), hectoliter weight (HW), protein content, ash content (ash), yield in semolina and in couscous, and the culinary quality of the couscous. Couscous from all entries were appreciated and considered as satisfactory. The selected lines showed a better adaptation to the environment. This selection allows us to develop and to make available to farmer's varieties adapted to local conditions (arid) with promising quality for a common food. The participatory selection was an effective tool to improve barley yield and yield stability, as well as the quality of barley products confirming the usefulness of the participatory model. The results showed the possibility of making good quality couscous with barley, which may open a new potential market for an old cereal.

Keyword: Adaptation; Participatory Plant Breeding; Consumer Preference; Couscous

Introduction

Barley (*Hordeum vulgare* L.) is with wheat, maize and rice, one of the most important cereal in the world, ranking fourth among cereal grain production (38% for maize 29% for wheat, 20 for rice and 6% for barley) (Saulnier 2012). Barley is an important food in many parts of the world such as North Africa, Near East, the Horn of Africa and Asia. It plays a key role not only as source of food in the Maghreb but also in the mountains of Ethiopia, Eritrea and Peru (Grando and Gomez-MacPherson 2005). In North Africa, Near East, the Horn of Africa and Asia, mean annual consumption per person varies from 2 to 36 kg (El-Haramein and Grando 2010). The grain of barley is an excellent source of fibers (ß-glycans and arabinoxylanes). Beta glycans, the main constituents of the fibers of the barley, are associated with the reduction in the plasma cholesterol, the improvement of the metabolism of lipids, and the reduction of the glycemic index (Marlett et al. 2002; Madhujith et al. 2006). It is also used as cattle feed in winter when the fodder deficit is large and feed prices are high. In Algeria, barley is widely cultivated, and is the second crop after durum wheat, with 35-40% of the area (Benmohammed 2004). In spite of the area dedicated to cereal, the national production is far from satisfying the needs of the population. The low yields are due to the combination of the several factors, which affect the technological and nutritional properties of cereals. The production of barley in dry zones has to cope with a number of climatic hazards. To improve barley production, the National Institute for Agricultural Research d'Algerie (INRAA) conducted a program of participatory plant breeding (PPB) starting from 75 lines and populations (thereafter lines) derived from crosses with adapted barley materials (Reguieg et al. 2013). The program took advantage from the participation of the farmers in the selection of the lines that they considered the best adapted to their environment and their agricultural system. At the end of the program, eight lines were selected and used for seed multiplication. In this paper we report the results of a study conducted to evaluate the technological characteristics of the eight lines selected from the PPB program, in comparison to the two check varieties (Rihane-03 and Saïda 183) widely grown in the region and taken as references byusing tools that allow the producer to select and evaluate the quality.

Material and Methods

Plant Material

The eight barley lines obtained at the end of the first participatory plant breeding cycle conducted in farmers' fields at various locations (Reguiet et al., 2013) were compared with the two barley varieties, Saida183 and Rihane-03, widely cultivated in Algeria.

Methods of analysis

The analysis was performed in the food technology laboratories at the University of Sidi Bel-Abbes to evaluate the physicochemical, biochemical and technological characteristics of eight barley lines. The analyses of the technological quality were conducted according to parameters used in similar studies (Rozenthal, 1975; Williams et al. 1988). Hectoliter Weight (HW) was determined by measuring the mass of barley grain in a volume by free flow of a sample through a funnel into a receptacle with a Nilema liter (NF V03-719/1981). The weight of one thousands whole (TKW) grains was determined using counter grains (Numigral) (NF V03-702/1981) after eliminating impurities. The Hagberg falling time was determined according to the standard (NF V 03-703/1997). The ash content was obtained by burning a sample of grains to a temperature of 900 °C according to the standard (NF 03-720/1981). The protein content was determined by the Kjeldhal method. The water content was also measured and the results expressed on a dry matter basis.

Evaluation of the barley semolina yield
The trial grinding:
Having cleaned and conditioned the barley by washing the grains, we conducted the grinding trial in a traditional arm grindstone formed by two superimposed stones. The size grading of the semolina S1 intended for the preparation of the couscous obtained was done by the passage of a trial taking of 100 gr in 0.1 gr meadows on a series of sieves classified in decreasing order by opening of stitches: 450μm, 800μm and 1000 μm. To characterize the granulation of the dry couscous, a trial grip of 100 grams in 0.1 meadows is depositing on the upper sieve of a series of sieves of opening of stitches of (630, 800, 1120, 1250 and 2500μm).

Evaluation of the Couscous value:
The preparation process of the (hand-rolled) home-made couscous is based on the agglomeration of the particles of semolina-water, precooking and free air drying during four days until a final humidity from 11.5 to 12 % is reached. The dry couscous yields of the semolina obtained from the different barley lines according was calculated with the following equation:

$$CY = (\text{Mass of the dry couscous}) / (\text{Mass of the used semolina}) \times 100$$

The traditional domestic cooking was done as described by Guezlane and Abecassis (1991). To determine the index of mass taking of the cooked couscous (ITCC), 10 gr of cooked couscous according to domestic cooking were put in capsules in railings metallic, the set was introduced into a steam room ventilated for a period of three hours and half at 60°C. The obtained product was put down on a sieve of 2500 μm for five minutes. The sieve refusal was expressed in percentage in comparison to the trial sample. The swelling index (SC) of the cooked couscous was evaluated as described by Guezlane and Abecassis (1991).

Sensory analysis of the cooked couscous
The culinary quality of the couscous, prepared according to the domestic method, was evaluated according to the conditions set by the standard AFNOR (NF V09-014, 1995). The essays of tasting were realized in the morning. Every plate contained approximately 20g to 30g of cooked couscous cooled toil 45°C. Plates were coded and presented together with the question forms. A jury compound of 6 subjects, already familiarized with the product, was invited to the sensory evaluation of the cooked couscous. The chosen criteria were: the sticky appreciated visually, the ease of decaking at the fork and the texture of the cooked products (firmness at the tooth).

Statistical analysis
Statistical analysis was performed using the Stat view 05 program (SAS Institute) (Caldorola et al., 1998). The results were expressed by calculating for each trait the mean and its standard deviation. Simple correlation coefficients were calculated between the different variables.

Results

Technological properties of the selected lines
The semolina value corresponds to the capacity of a cereal (barley or wheat) to give a yield in semolina of determined quality. This value can be estimated or appreciated by indirect tests following the physical) characteristics of the barley. **In Table 1,** we show the various physical characteristics of the eight selected barley lines and both checks. The physical characteristics of the eight barley lines are satisfactory in comparison with the two checks. The rates of humidity were very similar with an average of 9.57±0.32. The humidity of the cereal cultivated in Algeria and in particular of barley, is low compared with cereal of foreign origin. Based on the scale of classification (Godon, 1991), most of the barley lines show average kernel weight of 42-48g. The

highest TKW was observed for the line LS09 (45.7g) and the lowest for LS22 (39.3g). The determination of the TKW allows to judge the degrees of scalding of grains and to forecast the yield of semolina. The values of hectoliter weight (HW) are between 60.51 and 51.60 kg/hl with a mean value of 55.49 ±3.07. HW is used in Algeria as reference to establish the legislation regarding the rate of extraction of semolina or flours from the wheat (hard and soft). The HW of both check varieties and the line LS20 was low compared with all the other lines. Ash content was relatively low ranging from 2.48% (LS15 and Saida183) to 2.31% (LS17) with a mean value of 2.31±0.10. The Hagberg falling number (index of fall) value varies from 62 to 343 seconds with a mean value of 191.3 ±115.5. The semolina value indicates the capacity of a cereal (wheat or barley) to give, under industrial conditions, yield raised in semolina of a given purity. The flour represents only a low portion varying 2.11 to 5.56 % with a mean value of 3.4±1.01. The yields in semolina (YS) of both the check varieties and the eight selected lines are satisfactory and can be considered as good because they reached a maximum of 74% for the variety Rihane-03, 73.89% for the LS09 and a minimum of 60.4% for the variety Saïda 183 (62.71%) and for line LS22 with a mean value of 67.1±4.4%. The most important fraction of the semolina extracted from the quantitative point of view is the one superior to 400 µm (between 1250 and 400µm). This fraction (S1) was selected for the manufacture of our couscous. The ash is a characteristic of semolina purity. We consider that the value in minerals had only not much meaning and that the purity of a semolina could not be correctly appreciate by the determination of the ratio (R=ash semolina / ash grains), which must be lower than 0.5% (Guezlane, 1979).

Table 1. Water content (H_2O), Hectoliter weight (HW), thousand kernel weight (TKW), Hagberg falling number (I. Chute) of eight selected barley lines and of two check varieties

Entries	H_2O (%)	HW (kg/hl)	TKW (g)	Ash (%)	I. Chute (s)
LS05	9.10	54.36	44.55	2.33	63
LS09	9.37	55.06	45.71	2.26	241
LS15	9.69	56.32	45.41	2.48	327
LS16	9.27	56.91	43.88	2.24	62
LS17	9.42	57.54	44.86	2.18	70
LS18	9.79	58.74	45.65	2.34	275
LS20	9.62	51.57	42.28	2.27	213
LS22	10.15	60.51	39.34	2.33	343
Saida 183 (check)	9.37	52.32	44.72	2.48	63
Rihane 03(check)	9.89	51.60	44.35	2.20	256
Mean± sd	9.57 ± 0.32	55.49 ± 3.07	44.07± 1.9	2.31±0.1	191.3±115.43

HW: Hectoliter weight, TKW: thousand kernel weight, I. Chute: Hagberg falling number of barley flour

The quality of the semolina is determined by various physical-chemical and biochemical characteristics. Proteins have a key role in determining the technological quality of cereal (durum wheat or barley) for the manufacturing of pastas and couscous. The grading analysis of semolina was determined according to the method recommended by Calvel (1984). The grading distribution of a semolina allows to appreciate the behavior of semolina during the hydration (quantity of

absorbed water and speed of hydration) (Feuillet, 2000). The calibration is very important for obtaining a good hydration. All the semolina S1 presents more than 76% of the particles of size $\geq$ 800 μm. The most important are those fractions of the refusal of the sieve of 800 μm and 450 μm. The average values of the two refusals are 83.98±6.36 and 12.46±5.92. According to these values, we can conclude that semolina S1 of the various lines is homogeneous on the grading plan. These results coincide with the standards of the Codex concerning the preparation of the couscous. The protein content is very important in determining the quality of both the animal feed and the human food (value of use). In this study, the determination of the protein content aimed at specifying the role played by the total protein content on the quality of the couscous prepared from the various barley lines. The protein content of the semolina of the eight barley lines and of the two varieties was relatively high varying from 13.83 to 16.36 with a mean value of 15.27±1.01. The variety Saida and the lines LS09, LS17, LS18 and LS20 had the highest content (>16%). The line LS15 had the lowest value. These values agree with numerous studies of varieties of barley, the protein content of which varies between 12.9 and 18.6% (Belika et al., 2004) and from 10 to 17% (Kamal et al., 2013). The protein content of the same variety may change with the year and with the location. It is important to indicate that the lines and both check varieties were grown on well fertilized (with manure) land following one fallow and a second year of dried vegetables: this explains the relatively high values in total protein. The couscoussier value expresses the capacity of the semolina to give, under given conditions, a good quality couscous. The couscous is food the consumption of which widely exceeded the borders of the Maghreb from which it is native. The production process of barley couscous is still strongly based on the empiricism, the technological expertise and the know-how of the operators. Few scientific and technical works discuss the manufacturing process of the barley couscous.

Evaluation of the couscous yield

The preparation of products with semolina of barley at the level of the family home is a tradition for the people of North Africa. The barley couscous represents a traditional dish as well in Algeria as in Morocco, because is not only an energetic food, but also is an integral part of North Africa's food habits. The couscous results from agglomeration of the particles of semolina-water, is estimated by the rural and urban populations of the Maghreb. The different names with which couscous is called in North Africa, are associated with the mode of preparation and to the food habits: in Algeria it is called Tchicha and in Morocco it called Dchicha or Belboula (El Yamlahi et al. 2014). The balance assessment of the materials under study has allowed the evaluation of the technological feasibility of the preparation of couscous from only one type of barley semolina S1. In our essay, the couscous yields are significantly high for both the two checks and the eight lines. They vary from 68.34% to 88.43% with a mean value of 81.50 ±7.7. All the barley lines suits very well for the preparation of the couscous following the homemade method. The results of the granulation of the barley couscous are expressed, for every refusal of sieve, in percentage accumulated by the collected total mass and are presented in Table 2.

Table 2. Characterization of the granulation of the couscous

Entries	Refusal rate 2500 µm (%)	Refusal rate 1250 µm (%)	Refusal rate 1120µm (%)	Refusal rate 800 µm (%)	Refusal rate 630 µm (%)	Extraction 630 µm (%)
LS 05	0.21	53.11	24.84	19.26	1.39	0.85
LS 09	0.51	60.12	22.67	15.26	0.90	0.54
LS 15	0.26	79.01	12.33	6.12	0.82	0.60
LS 16	0.09	59.71	24.75	14.04	0.68	0.50
LS 17	0.15	73.29	15.95	8.21	0.30	0.15
LS 18	0.47	50.26	28.05	18.21	1.13	0.53
LS 20	0.90	75.34	13.85	7.59	0.89	0.57
LS 22	1.05	53.77	28.33	14.66	0.74	0.58
Saida 183	0.15	86.22	10.61	2.52	0.13	0.12
Rihane-03	0.02	67.48	21.84	9.46	0.32	0.41
Mean±sd	**0.38±0.35**	**65.83±12.28**	**20.32±6.59**	**11.53±5.53**	**0.73±0.39**	**0.48±0.21**
Minimum	0.02	50.26	10.61	2.52	0.13	0.12
Maximum	1.05	86.22	28.33	19.26	1.39	0.85

The grading distribution of the couscous shows the existence of a similarity between check varieties and the eight selected lines. The comparative study of the granulation of the dry couscous of the various barley lines shows that there was a wide difference between the samples although the conditions of preparation and the granulation of the used semolina were almost identical. The most important fraction is between the refusals of the sieves of 1250 and 1120 µm opening. These fractions vary between 50.26 and 86.22% and between 10.61 and 28.33%, respectively, with the mean values of both fractions equal to 65.83±12.28 and 20.32±6.59, respectively. The results of the distribution of size grading of the couscous of the various lines show that all the products present a size grading meeting the requirements of a big couscous (CODEX ALIMENTARIUS, 1995). The main factors of appreciation of a couscous are the index of mass taking of the cooked couscous (ITCC), the couscous Swelling Index (SC) and the test of tasting by the sensory evaluation. The couscous swelling index of water to couscous is a very important parameter to control the quality of products as well as industrial level during commercial transactions. The capacity of swelling of couscous is mainly related to the richness of the protein raw material as well as to their quality. According to Debbouz and Donnelly (1996), the capacity of couscous to absorb quickly the water and to maintain its firmness, are considered as good quality indicators compared with the couscous of the durum wheat. El Yamlahi et al. (2014) showed that a positive correlation exists between the protein quality, the protein content, the absorption of water and the couscous culinary quality. The evolution of the SC of the cooked couscous for every line according to time is shown in **Figure 1**. The Figure shows that the absorption capacity of water by the cooked couscous grains, handled by the water distilled at 100 °C differs from a line to another. This

difference is due to the quality of the raw material (protein content) as well as the granulation. We noticed that the speed of inflation of the couscous according to time was different. The analysis of the curves makes it possible to note that all the lines and the two varieties reached their maximum swelling after about twenty minutes of cooking. Debbouz and Donnelly (1996) confirm that the quantity of absorbed water increases with the degree of gelatinization of some starch.
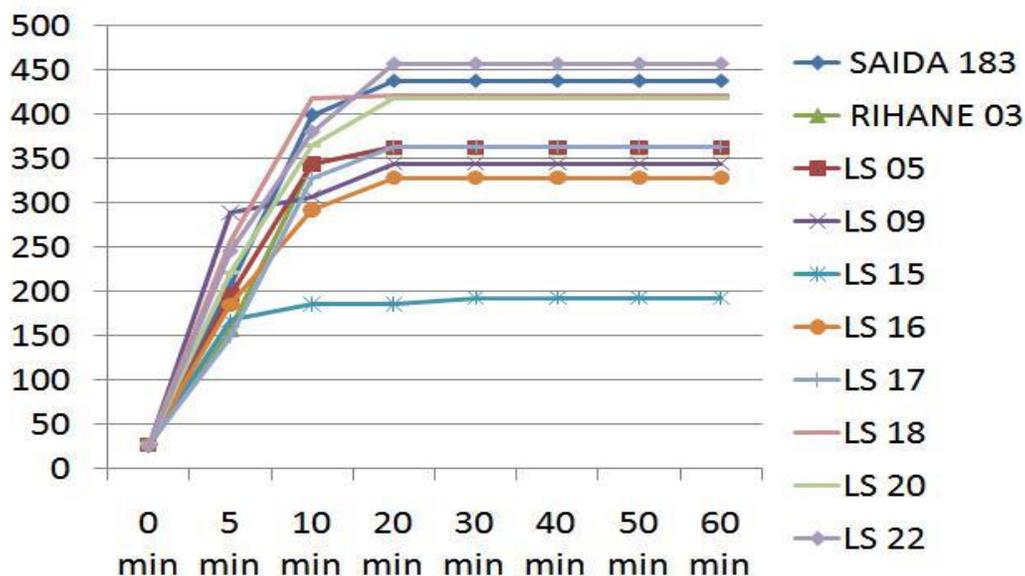

Figure 1. The swelling index (SC) of the cooked couscous in % of the couscous of the eight selected lines and the two check varieties as a function of time

The index of mass taking of the cooked couscous (ITCC) represents one of the criteria of evaluation of the organoleptic quality of the couscous. It reflects the physical state from agglomeration the couscous grains during the steam cooking followed by a drying. Its principle consists in hydrating and then in drying the couscous before submitting it to a grading analysis. ITCC was measured by the evaluation of the size of particles on a sieve of 2500μm of opening of stitch. The results of the indications of mass grip obtained for the couscous obtained from the two check varieties and the eight lines are shown in **Figure 2**. According to these results, the couscous was in general sticky. The couscous obtained from the variety Saida 183 was the least sticky while the couscous obtained from the variety Rihane-03 was the stickiest. In our trial, ITCC was very high for the check varieties and the eight lines. It varied from 27.5 to 65.8% with a mean value of 42.73±9.41.
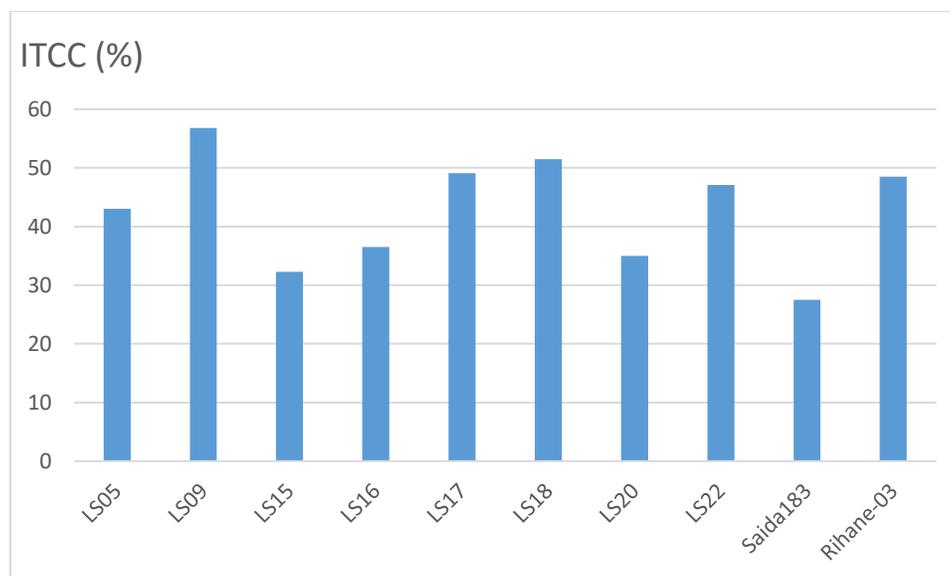
Figure 2. The index of mass taking of the cooked couscous (ITCC) in % of the eight selected lines and the two check varieties

Sensory evaluation of the culinary quality couscous
The culinary properties of the steamed couscous were estimated by a sensory analysis. Once cooked, the particles of couscous must be separated well without splitting nor sticking to each other. The results of scoring on a scale of 9 points of the sensory characteristics of the couscous, concerning the aspect and the regularity of the grains of couscous, the color, the tights and the firmness are shown in **Table 3**. The scores from 1 (= poor) to 9 (= best) were given by a jury of six people. Couscous of barley were considered rather firm but much less sticky and easier to demote with a good color. The mean values of the scores were 4.86 ± 0.58 for the firmness; 4.63 ± 1.26 for the tights; 6.38 ± 0.73 for the demottage, which characterizes the regularity of the couscous; 5.19 ± 1.0 for the color. By summing up the mean scores for the various criteria obtained for every couscous, allowed us (Table 3) to estimate an overall evaluation of the entries. The couscous obtained from the variety Saïda 183 received the highest total score (25.83) and was the most appreciated, followed by LS17 (23.49), LS16 (22.48). Generally, couscous made with the eight lines was estimated by all the ten tasters as being couscous of good taste presenting an acceptable firmness in spite of their little sticky character.

Table 3. Average scores of the various criteria used during the tasting of the couscous attributed to the eight selected lines and the two check varieties

Entries	Aspect and regularity of the grains of couscous *	Color *	Tights *	Firmness *	Sum of the averages	Rank of every product
LS 05	5.33	4.66	3.66	4.16	17.81	9
LS 09	6.5	4.5	3.16	4.5	21.66	6
LS 15	6.33	4.16	6.5	5.66	22.65	4
LS 16	6.66	6.33	5.33	4.5	22.82	3
LS 17	6.83	7.16	4.33	5.16	23.48	2
LS 18	6.66	4.16	3.5	5.16	19.48	8
LS 20	6.83	5.83	5.66	4.33	22.65	4
LS 22	5	4.5	3.66	4.33	17.49	10
Saida 183	7.5	5.5	6.5	5.83	25.33	1
Rihane 03	6.16	5.16	4	5	20.32	7
Mean ±sd	**6.38±0.73**	**5.19±1.0**	**4.63±1.26**	**4.86±0.58**	**21.37±2.54**	
Minimum	5.0	4.16	3.16	4.16	17.49	
Maximum	7.5	7.16	6.5	5.83	25.33	

* The note 1= not firmness = very tight =irregularity des grains of couscous (difficult to demotte)
* The note 9=firmness= not tight = Very easy in demotte with a good color by the consumer

Relation between the physical-chemical characteristics of the semolina, the instrumental and sensory analyses of the couscous

Table 4 summarizes the physical-chemical characteristics of the semolina, the instrumental and sensory analyses of the couscous of the eight selected lines and the two checks. To estimate the capacity of the measures made to predict the quality of the couscous, the matrix of correlation coefficients between the physical-chemical characteristics of the semolina, the instrumental and sensory analyses of the couscous of the eight selected lines and the two checks was estimated.

Table 4. The characteristics of the semolina S1 and the characteristics of the couscous of barley

Entries	GS1 (%)	TP (%)	SC (%)	ITCC (%)	Dem	Light	Firmness
LS05	79.75	15.31	362.96	43	5.33	3.66	4.16
LS09	73.88	16.28	344.44	56.8	6.5	3.16	4.5
LS15	81.96	13.83	192.86	32.3	6.33	6.5	5.66
LS16	89.70	14.44	328.57	36.5	6.66	5.33	4.5
LS17	90.79	16.01	364.29	49.1	6.83	4.33	5.16
LS18	82.51	16.36	421.43	51.5	6.66	3.5	5.16

LS20	85.24	16.19	417.86	35.0	6.83	5.66	4.33
LS22	86.16	14.09	457.69	47.1	5	3.66	4.33
Saida183	93.61	16.01	438.46	27.5	7.5	6.5	5.83
Rihane-03	76.23	14.26	362.96	48.5	6.16	4	5
Mean ±sd	83,98±6,36	15,27±1,01	369,1±75,4	42,73±9,47	6,38±0,73	4,63±1,26	4,86±0,58
Minimum	73,88	13,83	192,86	27,5	5	3,1	4,1
Maximum	93,61	16,36	457,69	56 ,8	7,5	6,5	5,83

The protein content was weakly correlated with the firmness (0.32) and to the tights (0.18) which is surprising because the culinary quality of couscous improves with the increase of the quantity and the quality of proteins (Debbouz et al, 1994). The explanation is that perhaps it is the quality of proteins that plays a major role in predicting the culinary quality. The demottage was positively correlated to the firmness (0.59). ITCC was negatively correlated with the sticky character (r= -0.94). The results found did not confirm the theoretical data of durum wheat couscous since the ITCC follows the sticky diffusion of starch on the surface of couscous Guezlane and Abecassis (1991).

Conclusion

The main objective of this study was to characterize the physicochemical and technological parameters of eight barley lines derived from one cycle of PBB and to compare them with two commonly grown varieties. This first attempt of participatory selection in Algeria has shown clearly that it is possible to introduce new varieties of barley under semi-arid conditions. The aim of PPB is not only to get good performance with well-adapted varieties, but also to improve the cultivation of barley, the regularity of yields and the quality. The grinding on grindstone after conditioning of the two variety and the eight lines gave satisfactory rates of extraction very similar for ten samples with yields (efficiencies) in semolina ranging from a minimum of 58.88 % for LS22 up to a maximum of 73.89 % for LS 09. The rate of flour was very low reaching a maximum of only 5.56%. The measure of the semolina value by the essay of traditional grinding shows the lines that has high rates of extraction. The results of the distribution of size grading of the couscous of the various lines showed that all the products present a size grading meeting the requirements of a big couscous. The tasters judged couscous rather firm and sticky with an aspect characterized for all samples by the regularity of the shape and by the tanning of the color. However, all the couscous was appreciated and considered as satisfactory. Our results show the possibility of making good quality couscous with barley and this is going to open a new market potential to an old cereal.

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