

Physico-chemical, malting and biochemical properties of some improved Nigerian barley cultivars and their malts

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Abstract

Five improved Nigerian barley cultivars (ESCOBA, ASE-2, ALOE, GOB-2, SUMBARD) were obtained from Lake Chad Research Institute Maiduguri, Nigeria, and their physicochemical, malting and biochemical properties investigated employing standard procedures. Data were analyzed by means of ANOVA [at 95% significant level] and correlations using SPSS 14 software. Results showed GOB-2 grain and malt recording the highest kernel weight (47.50 g) and kernel volume (41.21 ml); whereas ALOE grain had the longest kernel length (13.40 mm) and GOB-2 the shortest (9.40 mm). GOB-2 had the largest major diameter (3.39 mm) and SUMBARD had the least (2.86 mm). ESCOBA, SUMBARD and ASE-2 cultivars had the highest protein values (as %N) of 14.90%, 13.90% and 13.69% respectively, while ALOE, ASE-2 and GOB-2 had the highest total carbohydrates of 69.97, 69.39 and 68.90% respectively. All the cultivars had good germinative capacities (> 90%), with GOB-2 and ASE-2 having the highest germinative energy values of 96.65% and 95.00%. No significant ($p > 0.05$) changes in the dimension of the kernels after malting. SUMBARD recorded the highest malt yields (88.55%) followed by ASE-2 (83.45%) and ALOE (82.00%). The highest α -amylase activities of 105.34 and 96.23 unit/mg protein/min were recorded by ASE-2 and ALOE, respectively, with corresponding diastatic powers of 81.92 and 76.23°L. Thousand kernel weight correlated positively with protein ($r = 0.500$, $P < 0.05$) and with total soluble solids ($r = 0.435$, $p < 0.05$) but negatively with α -amylase ($r = -0.869$, $p < 0.05$) and with diastatic power ($r = -0.838$, $p < 0.05$). This study showed that the cultivars have good potentials for use as malting materials in beverage making.

Keywords

Nigerian barley
malting properties
cultivar
malting

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Introduction

Barley (*Hordeum vulgare* L.) is the traditional cereal used in the production of malt; the principal material for both alcoholic and non-alcoholic beverages. Attempts have been made by scientists around the world particularly Africa to malt other cereal grains to partially or completely substitute barley, but none of the malt drink had organoleptic properties comparable to the one produced from barley malt. Furthermore, apart from the appropriate levels of diastatic enzymes that are synthesized during germination, the physiological processes that accompany optimum modification of the barley kernels placed barley far above other cereals (Hough, 1991; Demuyakor *et al.*, 1994; Agu, 1995). Unfortunately, most of the barley malt used in Nigeria is imported and this drains the country of its foreign exchange.

In view of the aforesaid findings, successive governments in Nigeria have encouraged companies and research institutes to cultivate barley in the

country. In pursuance of this programme, the Federal Government of Nigeria mandated Lake Chad Research Institute Maiduguri to develop malting barley with local adaptation. The Institute has been experimenting and reporting the yields and agronomic characteristics of barley cultivars but the physicochemical, malting and biochemical properties of the grain, malt and malt drinks produced thereof have been neglected. However, Makeri *et al.* (2011) have reported on the quality of malt beverages produced from some of the barley cultivars grown by Lake Chad Research Institute, Maiduguri, Nigeria. Therefore, there is an urgent need to determine the physical, chemical, malting and biochemical properties of these improved barley grains developed in Nigeria by Lake Chad Research Institute, Maiduguri as this information will be useful for certification of the cultivars as malting grains.

The objectives of this study therefore were to determine the physical, malting and biochemical properties of ESCOBA, ASE-2, ALOE, GOB-2, and SUMBARD barley cultivars and their malts.

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Materials and Methods

The barley cultivars (ESCOBA, ASE-2, ALOE, GOB-2, and SUMBARD) were obtained from the Lake Chad Research Institute Maiduguri. The grains were cleaned to remove impurities of sand and plant matters before the study.

Physical analysis

The weight and volume of 1000 barley kernels were determined in triplicates as described by Gomez *et al.* (1997). Density was calculated as a ratio of mass of the kernel to its volume in gram per millilitres (Nelkon and Parker, 1995). The two principal dimensions of the grain (length and breadth diameters) were measured using a micrometer screw gauge with accuracy of 0.01 mm.

Chemical analysis

The chemical Properties of the Barley cultivars including moisture, fats, total carbohydrates, protein and ash were determined according to AOAC (1990), and total carbohydrates obtained by difference. Nitrogen was determined using Kjeldahl method and protein calculated as total Nitrogen x 6.25. Moisture was obtained as a weight loss after oven drying at 110°C for 2 hr. Fat was obtained in a 4 hr continuous extraction using petroleum ether (B.P. 40-60°C) as solvent. Ash was found from the weight remaining after incineration of the barley sample at 550°C for about 5 hr. The pH and titratable (in triplicates) acidity of the malt were determined using standard assays (AOAC, 1990). The pH of the malt sample was determined using glass-electrode Kent pH meter (Kent Model 7020). About 50 g of dried malt was ground using Laboratory Disc Mill and homogenized in 100 ml distilled water. The water was decanted and its pH determined after calibration of the pH meter using pH buffer 4.0 and pH 7.0. Titratable acidity (as % citric acid) was determined by titrating 25 ml of the homogenized malt-water mixture (filtered using Whatman No 1 filter paper) against 0.1M NaOH to the phenolphthalein end point (James, 1999).

$$\% \text{ Citric acid} = \frac{T \times 192}{3 \times 1000}$$

The total soluble sugar (as %Sucrose) was determined with Abbey's refractometer (Brix = 0 to 32%) and the results expressed as percent (%) total soluble sugar (TSS). The prism and the lid of the instrument were first cleaned with moistened cotton wool, the aperture opened and the instrument switched on to allow temperature to equilibrate. It was then adjusted

to read R.I. = 1.33 using distilled water. A few drops of the malt drink were placed on the upper prism and the lower lid tightly closed to ensure a thin film of the malt beverage sample. The reading was then taken when the angles of incident and of the refracted rays, as observed through the aperture, aligned at the interface between the two media (James, 1999).

Germinative energy

The germinative energy was determined following the method of the Institute of Brewery (1986). Accordingly, one hundred barley kernels grains were placed on two filter papers (Whatman No. 1) wetted with 4 ml of distilled water placed at the bottom of a Petri dish, taking care to ensure that all the kernels were in good contact with the moist filter papers. The Petri dish was then covered and incubated at an average temperature of 30°C for 24-48 hours. The kernels that shoot (sprouted) at the end of the incubation were counted and expressed as germinative energy (Pollock, 1962; Agbo, 1996). $GE (\%) = 100 - N$; where; GE=Germinative Energy and N = number of ungerminated grains.

Germinative capacity

One hundred barley grains were placed in a 100 ml glass beaker containing 7.5% hydrogen peroxide (H_2O_2) solution and steeped at 30°C for 48 hours. The steep water was strained off and the sprouted grains separated from the un-sprouted ones and counted. The un-sprouted grains were then transferred onto moist filter papers (Whatman No.1) in petri dishes covered with another moist filter paper and the lid replaced. The dishes were then wrapped in jute bag and allowed to germinate at ambient temperature ($32^\circ C \pm 2$) for about 24 hours while water was sprinkled at intervals. Newly germinated grains were counted and the result added to the first (Agbo, 1996; Badau, 2004). The germinative capacity (GC) was calculated as follows:

$$GC \% (H_2O_2) = \frac{(200 - N)}{2}$$

where; N = Number of ungerminated grains.

Water sensitivity

Two lots of 100 grains each were grown on filter papers (Whatman No.1) in petri dishes (9 cm diameter); one moistened with 4 ml and the other with 8 ml water. The difference in the number of grains that germinated in the two Petri dishes was noted as the water sensitivity value (Wainwright and Bukee, 1977; Briggs *et al.*, 1981; Singh and Sosulki, 1985).

Water absorption

Hundred (100) barley kernels of each cultivar were soaked in a 100 ml beaker containing 50 ml of distilled water at ambient temperature ($32^{\circ}\text{C} \pm 2$). Steeping was done continuously until constant weights were attained and recorded. Soak waters were drained off the grains by the use of sieves, while soaked grains were weighted at 60 minutes interval; from 0 hr to 12th hr, and 2 hrs intervals; from the 12th to the 24th hr. The water absorbed over the 24 hrs soaking period was calculated as the difference between the weights of the original and soaked grains (Badau, 2004).

Malting

Malting consists of steeping, germination and drying or kilning of cereal grains. The barley grains were steeped at $32^{\circ}\text{C} (\pm 2)$ as follows: 8 hrs steeping: 4 hrs air-rest: 8 hrs steeping: 4 hrs air-rest, for 24 hrs. Air-rests were done by draining off the steep water completely. After the last 4 hrs air-rest, the grains were placed on a cotton cloth sterilized with sodium hypochlorite (3.5% in 175 ml distilled water), covered with jute bag and germinated at room temperature ($32^{\circ}\text{C} \pm 2$) with water sprinkled at intervals (Morral et al., 1986; Badau, 2004). The green malts were harvested after 72 hours of continuous germination and dried in air-oven at an initial temperature of 35°C for 30 hours, and then final drying at 55°C for 12 hours to a moisture content of $5.8 \pm 0.44\%$. The polished malts were milled into flour using attrition mill to pass through 1mm mesh screen, packaged in plastic containers and stored in wooden cupboard before use (Aniche and Palmer, 1990).

Total malting loss

The total malting loss (respiratory loss, vegetative loss and green malt moisture loss) was found by subtracting the weight of the polished malts from the weight of the original barley grain expressed as a percentage (Gomez et al., 1997).

Diastatic power

Diastatic power was determined using the Ferricyanide Method (IOB, 1986). Malt extract was obtained by extracting with water for 2 hours in a temperature-controlled water bath (Temperor^(R) England). About 3 ml of the unfiltered malt-extract supernatant was transferred in to a 250 ml Erlenmeyer flask containing 100 ml buffered starch solution maintained at 30°C in a water-bath. After 1 hr thorough mixing, 5 ml portion of digested starch solution was mixed with 10 ml of alkaline ferricyanide and left to stand in boiling water for 20 min. On cooling

to 30°C , 25 ml acetic acid salt and 1 ml potassium iodide solutions were added and the solution titrated with 0.05 mol/l sodium thiosulphate solution to the complete disappearance of the blue colour thus formed. A blank was prepared of the unfiltered malt infusion and 2% buffered starch solution (Meredith et al., 1962).

The diastatic power (Dp) was calculated as follows:

$$\text{Dp (IOB)} = \text{B-A} (23 \times 200 / 250 \times 1 / \text{C})$$

where:

A = volume of sodium thiosulphate used for direct titration.

B = volume of sodium thiosulphate used for blank determination.

C = volume of unfiltered malt extract used for the digestion.

The diastatic power Dp ($^{\circ}\text{IOB}$) was converted to Dp ($^{\circ}\text{L}$) as follows: $\text{Dp} (^{\circ}\text{L}) = \text{DP} (^{\circ}\text{IOB}) \times 1.1$ (IOB, 1986; Agbo, 1996; and Badau, 2004).

Alpha-amylase activity

This was determined according to A.O.A.C., (1990). Two grams of each of the malt flours was mixed with 10 ml of iced water and centrifuged for 10 mins at 800 rpm to obtain the supernatant enzymes extract. About 4 ml of phosphate buffer (pH 6.6), 1 ml sodium chloride and 1 ml of the enzyme extract were mixed with 5 ml of soluble starch solution in a test tube, and aliquots (0.2 ml) of the reacting mixture were taken at 5 mins intervals starting from zero minute. The aliquot was placed in the cuvette of a colorimeter and the absorbance measured to obtain seven readings.

Analysis of data

Analysis of variance (ANOVA) was carried out using SPSS 14 Software Package (1999) to determine level of significance at 95%. Test of association was done using Pearson's two-tail correlation-coefficient between the various components.

Results and Discussion

Physical properties of the barley grains and malts

There were significant variations in some physical characteristics of the barley samples ($P \leq 0.05$). 1000-kernel weight ranged from 37.20g for ASE-2 to 47.50 g for ESCOBA. 1000-kernel volume ranged from 32.20 mm³ for ASE-2 to 41.00 mm³ for ESCOBA, as shown in Table 1. The grain length varied from 9.40 mm for ESCOBA to 13.40 mm for ASE-2, while the major diameter varied from 2.86 mm to 3.39 mm for

Table 1. Physical properties of the barley grains and malts^{1,2}

		BARLEY CULTIVAR					
		ESCOBA	GOB-2	ALOE	ASE-2	SUMBARD	
Thousand weight(g)	Kernel	GRAIN	43.60 ± 0.76 ^a	47.50 ± 1.06 ^b	39.40 ± 0.84 ^c	37.20 ± 0.60 ^c	39.50 ± 1.56 ^c
		MALT	38.31 ± 1.23 ^a	40.46 ± 1.14 ^a	34.40 ± 1.07 ^b	31.65 ± 0.98 ^c	34.67 ± 2.01 ^b
Thousand volume (ml)	kernel	GRAIN	39.67 ± 1.30 ^a	41.00 ± 0.67 ^a	35.00 ± 0.71 ^b	32.20 ± 1.60 ^c	35.00 ± 0.76 ^b
		MALT	38.16 ± 1.56 ^a	41.21 ± 1.78 ^a	34.94 ± 2.14 ^b	31.86 ± 2.11 ^c	35.63 ± 1.68 ^b
Density (g/ml)	GRAIN	GRAIN	1.10 ± 0.76 ^a	1.16 ± 1.75 ^b	1.13 ± 2.13 ^a	1.15 ± 1.76 ^b	1.13 ± 1.98 ^{b*}
		MALT	1.00 ± 0.68 ^a	0.98 ± 1.55 ^a	0.99 ± 1.65 ^a	0.99 ± 0.87 ^a	0.97 ± 0.35 ^a
Grain length (mm)	GRAIN	GRAIN	10.00 ± 1.04 ^a	9.40 ± 0.91 ^a	13.40 ± 0.17 ^b	11.10 ± 1.91 ^c	13.00 ± 1.06 ^b
		MALT	9.21 ± 2.01 ^a	9.02 ± 1.19 ^a	13.06 ± 1.06 ^b	10.97 ± 0.98 ^c	12.67 ± 1.23 ^b
Major Diameter (mm)	Grain	GRAIN	3.34 ± 0.19 ^a	3.39 ± 2.91 ^a	2.90 ± 1.08 ^b	3.24 ± 0.94 ^a	2.86 ± 1.01 ^b
		MALT	3.21 ± 1.66 ^a	3.16 ± 1.13 ^a	2.60 ± 0.98 ^b	3.00 ± 1.03 ^a	2.11 ± 1.09 ^c
Minor Diameter (mm)	Grain	GRAIN	2.29 ± 0.12 ^{b*}	2.30 ± 0.61 ^{b*}	2.37 ± 0.15 ^a	2.38 ± 0.62 ^a	2.39 ± 0.62 [*]
		MALT	2.10 ± 1.32 ^{**}	2.20 ± 2.41 ^b	2.16 ± 2.31 ^{b*}	2.03 ± 1.03 ^c	2.16 ± 1.20 ^a

¹Values are means of triplicates determinations. ²Means horizontally along a column not followed by the same letter are significantly different ($p < 0.05$) based on cultivar.

*Values are means of duplicates determination.

ESCOBA. After malting, there were not significant ($p > 0.05$) changes in most of the physical properties of the resulting malts. The texture of the endosperm influenced the malt modification process by affecting water uptake and consequently enzyme synthesis and movement within the endosperm (Chandra *et al.*, 1999). From the different quality parameters reported in the literature, fast hydration and germination (Ulonska and Baumer, 1976; Briggs 1998), kernel size fractions, kernel weight, β -glucan and protein contents, malting losses, friability, α -amylase activity, soluble nitrogen ratio (SNR) and viscosity (Fox *et al.*, 2003) are among the common assays used to test the quality of barley grain for malting. In addition, endosperm structure, starch content, protein content, and cell wall properties have, among others, been identified as factors determining the rate of water uptake during barley steeping (Ogushi *et al.*, 2002). Anderson *et al.* (1999) studied the variation and correlation between chemical and physical characteristics of barley samples including kernel hardness, but found only a low correlation between kernel hardness and physical and chemical grain properties.

Chemical compositions of the barley grains and malts

Table 2 showed slight but significant ($p < 0.05$) variations in the proximate compositions of the barley grains. ESCOBA had the highest protein, ash and carbohydrates contents of 14.9%, 3.33% and 69.67% respectively. The fat content showed slight variations between the five barley cultivars. Likewise the ash content of all the barley grains showed variations within the cultivars. GOB-2 and ESCOBA had the highest ash content of 3.23% and 3.33% respectively. There were no significant differences ($p > 0.05$) in the ash content of the other three cultivars. There

Table 2. Chemical composition of barley grains and malts^{1,2}

		BARLEY CULTIVAR					
		GOB-2	ESCOBA	ALOE	ASE-2	SUMBARD	
Moisture	Grain	Grain	11.60 ± 1.29 ^a	11.10 ± 1.67 ^a	11.25 ± 0.17 ^a	11.12 ± 0.92 ^a	10.50 ± 1.87 ^b
		Malt	6.51 ± 0.45 ^a	5.58 ± 1.21 ^b	6.01 ± 0.41 ^a	5.42 ± 1.91 ^b	5.83 ± 1.82 ^b
Protein	Grain	Grain	12.80 ± 0.91 ^a	14.9 ± 1.46 ^b	12.08 ± 0.67 ^a	13.69 ± 1.06 ^a	13.90 ± 0.54 ^b
		Malt	12.32 ± 1.73 ^a	12.13 ± 0.37 ^a	11.80 ± 13.00 ^a	13.00 ± 0.67 ^b	13.10 ± 0.97 ^b
Crude fat	Grain	Grain	3.41 ± 1.37 ^a	3.90 ± 0.70 ^a	3.86 ± 1.26 ^a	3.20 ± 1.10 ^a	4.12 ± 0.81 ^b
		Malt	3.56 ± 0.56 ^a	4.13 ± 0.76 ^b	3.10 ± 0.69 ^a	3.21 ± 0.98 ^a	4.07 ± 1.20 ^b
Minerals	Grain	Grain	3.23 ± 1.90 ^a	3.33 ± 1.57 ^a	2.90 ± 1.09 ^b	2.60 ± 1.64 ^b	2.66 ± 1.33 ^b
		Malt	3.01 ± 1.33 ^a	3.12 ± 1.90 ^a	2.51 ± 0.18 ^b	2.58 ± 1.09 ^b	2.42 ± 1.05 ^b
Carbohydrates	Grain	Grain	68.90 ± 1.30 ^a	68.67 ± 2.50 ^a	69.97 ± 2.00 ^b	69.39 ± 1.90 ^b	68.84 ± 1.87 ^a
		Malt*	75.69 ± 0.48	75.15 ± 1.13	75.60 ± 0.19	75.90 ± 2.69	74.60 ± 0.12

¹Values are means of triplicates determinations. ²Means horizontally along a column followed not by the same letter are significantly different ($p < 0.05$) based on cultivar.

*Values are means of duplicate determinations.

were however significant differences ($p < 0.05$) in the carbohydrate content of the cultivars. ALOE had the highest (69.97%) and ESCOBA had the least (68.67%). ASE-2 had the highest total carbohydrates content (75.90%) followed by GOB-2 (75.69%) and ALOE (75.60%). The chemical properties of the grain and the resulting malts compared, showed little but significant ($p < 0.05$) variation in the protein contents. The significant ($p < 0.05$) change in the carbohydrates may have resulted from the proportionate decreases in the moisture and other polysaccharides. The high carbohydrate contents will yield high enough fermentable sugars and consequently high beverage output.

Germination properties of the barley grains

Except for the germinative capacity, there were significant variations in the germinative properties of the barley cultivars. As shown in Table 3, the germinative energies of the barley cultivars ranged between 93.76% for ESCOBA and 96.65 for % GOB-2. SUMBARD had the highest water sensitivity (5.06%) and ESCOBA had the least (1.12%). The cultivars GOB-2 and SUMBARD showed moderate sensitivity to water, while ESCOBA and ALOE showed little or no sensitivity to water. Malting loss varied from 11.48% to 24.00% for SUMBARD and ESCOBA, while malt yield varied from 76.00% to 88.55% for ESCOBA and SUMBARD respectively. All the barley grain showed satisfactory germinative properties good for grains intended for malting as they had over 90% germination. Similar results have earlier been reported by other workers. All the cultivars exhibited over 95% germination capacities; an indication to exhibit low dormancy when germinated under optimum conditions. High germinating capacity and/or germinating energy, low malting loss and/or high malt yield, high and rapid uniform germination are essential features of good malting barley (Meredith *et al.*, 1962). Warm

steeping facilitates rapid water absorption which may not permit even distribution of moisture within the barley kernel. However, Badau (2004) reported that warm steeping facilitates water absorption, but cold steep has been associated with more uniform steeped kernel in pearl millet. The rates of water uptake varied significantly between 34.50% and 29.25%. ASE-2 had the highest water absorption rate while ALOE the least.

Table 3. Germination properties of the barley malts ^{1, 2}

Property (%)	BARLEY CULTIVAR					
	GOB-2	ESCOBA	ALOE	ASE-2	SUMBARD	
Germinative capacity (%)	98.01 ± 1.67*	97.79 ± 1.78*	98.67 ± 0.95*	96.96 ± 1.21*	98.28 ± 0.38*	
Germinative Energy (%)	96.65 ± 1.12 ^a	93.76 ± 1.02 ^a	94.11 ± 0.65 ^b	95.01 ± 1.04 ^b	94.56 ± 1.09 ^b	
Water (%) sensitivity	4.29 ± 0.56 ^a	1.12 ± 1.45 ^b	3.12 ± 2.01 ^c	2.10 ± 1.06 ^d	5.06 ± 1.09 ^e	
Malting loss (%)	21.85 ± 2.16 ^{a*}	24.00 ± 1.08 ^b	18.00 ± 1.29 ^c	16.55 ± 0.64 ^c	11.45 ± 0.96 ^d	
Malt yield (%)	78.15 ± 1.23 ^a	76.00 ± 1.96 ^b	82.00 ± 2.46 ^c	83.45 ± 2.01 ^d	88.55 ± 0.91 ^e	
Water uptake at 32°C (± 2)	0-12 hrs	30.00 ± 1.16 ^a	32.15 ± 2.32 ^b	29.50 ± 0.59 ^a	34.20 ± 1.41 ^c	32.13 ± 2.16 ^b
	12-24 hrs	42.07 ± 1.17 ^a	43.45 ± 0.29 ^b	40.07 ± 2.12 ^c	44.45 ± 2.07 ^b	42.27 ± 1.89 ^a

¹Values are means of triplicates determinations. ²Means horizontally along a row not followed by the same letter are significantly different (p < 0.05) based on cultivar. *Values are means of duplicates determinations.

Biochemical properties

Alpha-amylase varied significantly (p < 0.05) from 84.61 unit/mg protein/min. for GOB-2 to 105.34 unit/mg protein/min. for ASE-2. ASE-2 had the highest value of 81.92°L, while ESCOBA had the least. The titratable acidity (as % lactic acid) ranged from 1.35% for SUMBARD to 2.01% for ESCOBA, while total soluble solids (as sucrose) ranged from 9.83% for SUMBARD to 13.49% for ESCOBA. The cultivar [ESCOBA] suffered the highest malting loss of 24%. This loss (comprised of physiological, moisture and vegetative loss) was inversely related to the malt yield. The cultivar SUMBARD which had the least malting loss recorded the highest malt yield. Malt yield is a critical factor in malting as it reflects the amount of extracts obtainable from cereal grain concerned. Yield of extracts is as important to a malt producer and brewer as yield of grain to a barley grower. Differences in malting characteristics of the barley may be attributed to their physiological and structural differences (Etokakpan and Palmer, 1990).

Correlations between physical, chemical and biochemical properties of the barley

Thousand kernel weight correlated positively with protein (r = 0.500, P < 0.05), with fat (r = 0.500, P < 0.05), but correlated negatively with carbohydrates (r = -0.800, P < 0.05) and with moisture (r = -0.100, P < 0.05). A positive correlation existed between protein and fat (r = 0.500, P < 0.05), protein and ash (r = 0.200, P < 0.05), and highly negatively significant between

protein and carbohydrates (r = -0.900, P < 0.05). Thousand-kernel weight was negatively correlated with α-amylase (r = -0.869, p < 0.05), with diastatic power (r = -0.838, p < 0.05); positively with titratable acidity (r = 0.632, p < 0.05), with total soluble solids (r = 0.435, p < 0.05) and highly positively correlated with pH (0.700, p < 0.05). A highly negative but significant correlation existed between 1000-kernel volume and α-amylase (r = -0.927, p < 0.05) and with diastatic power (r = -0.779, p < 0.05). Grain density was negatively correlated with diastatic power (r = -0.246, P < 0.05), positive with total soluble solids (r = 0.430, p < 0.05) and highly positively correlated with titratable acidity (r = 0.702, p < 0.05). Minor diameter was significantly correlated with pH (r = -0.909, P < 0.05) but positively correlated with alpha amylase (r = 0.723, P < 0.05) and with diastatic power (r = 0.490, P < 0.05). Diastatic power was negatively correlated with titratable acidity (r = -0.442, P < 0.05), with total soluble solids (r = -0.018, P < 0.05) and with pH (r = -468, P < 0.05).

Table 4. Biochemical properties of the barley cultivars ^{1, 2}

Cultivar	Alpha-amylase	Diastatic power	Titratable acidity	T. S.S	pH*
	(Unit/mg protein/min.)	(°L)	(%)	(as % sucrose)	
GOB-2	86.56 ± 3.61 ^a	73.62 ± 0.67 ^a	1.50 ± 0.90 ^a	12.19 ± 0.90 ^a	5.50 ± 0.45
ESCOBA	84.61 ± 1.80 ^b	61.57 ± 1.2 ^b	2.01 ± 0.65 ^b	13.49 ± 1.61 ^b	5.41 ± 0.09
ALOE	96.20 ± 2.56 ^c	76.23 ± 1.67 ^c	1.60 ± 1.62 ^a	12.01 ± 0.80 ^a	5.32 ± 1.89
ASE-2	105.34 ± 2.8 ^d	81.92 ± 0.91 ^d	1.65 ± 0.79 ^a	12.88 ± 1.17 ^a	5.27 ± 1.89
SUMBARD	90.67 ± 1.57 ^e	69.27 ± 1.98 ^e	1.35 ± 0.76 ^a	9.83 ± 0.21 ^c	5.33 ± 1.01

¹Values are means of triplicates determinations. ²Means horizontally along a row not followed by the same letter are significantly different (p < 0.05) based on cultivar. *Values are means of duplicates determinations. TSS: total soluble solids.

Conclusion

The barley cultivars studied showed good potential for use as malting grain especially ESCOBA, GOB-2, ALOE and SUMBARD. With the exception of ASE-2, all the cultivars showed good physical properties for a malting material and good germinative properties [Ger. Cap. >95%; Ger. Ener. >90%; Malt Yield >70%]. Physical and biochemical properties such as kernel weight, diastatic properties, malt yield and fermentable sugars are critical in the preliminary evaluation and selection of grain for malting. However, further studies on the optimum modification conditions for the cultivars, friability index of the malts, component fermentable sugars and free amino nitrogen (FAN) need to be undertaken before final certification of the cultivars for malting purposes.

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