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BREWING WITH BUCKWHEAT AND SORGHUM: IMPACT ON BEER QUALITY

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Abstract: In the process of obtaining gluten-free beer, various non-conventional raw materials were used. Some of these have shown real potential in obtaining quality finished products appreciated by consumers. In addition to health issues, several factors also play a role in the choice of these raw materials, one of which is the climate changes that are occurring around the globe. The paper summarizes our own research on the use of two of these non-conventional materials, buckwheat and sorghum, in unmalted form in the technological process of obtaining beer at microbrewery equipment. Through the research carried out, it was aimed to establish optimal conditions for mashing-saccharification and fermentation-aging processes that would lead to a quality finished product. The best results in terms of sensory and physico-chemical characteristics were achieved by beer obtained from 50 % unmalted buckwheat and 50 % unmalted sorghum.

Keywords: *gluten-free beer*, *non-conventional raw materials, unmalted buckwheat, unmalted sorghum*

INTRODUCTION

Barley malt is the preferred grain used in traditional brewing processes. Through the malting process, barley undergoes biochemical transformations that generate the essential enzymes, carbohydrates and proteins necessary to produce wort. Barley malt forms the basic raw material for obtaining beer, however, the partial replacement of barley with cereal adjuncts such as wheat, maize and rice is well established in the brewing industry. Global climate change is expected to have important consequences for barley production. Crop and economic models have forecast that extreme weather events can cause substantial declines in barley production worldwide, with a potential loss of 17 % under the most severe conditions. The decline in global barley supply could drive beer prices up by 193 % by 2099, according to some forecasts.

Therefore, the use of a wider range of adjuvants may play a role in ensuring the supply of raw materials for brewing in a period of projected climate change. For example, climate change has been predicted to have no significant negative effects on maize production in the US and China [1]. Using unmalted ingredients can significantly reduce cost, as the malting process is an energy-intensive process and can reduce the carbon footprint of brewing. These factors prove to be of paramount importance when it comes to producing a quality beverage with distinctive characteristics in terms of flavor and organoleptic quality [2].

On the other hand, the demand for gluten-free beer consumption has recently increased. Barley contains gluten-generating proteins, the protein fraction also presents in wheat, rye, oats and their cross-breed variations to which some people are intolerant. These people must follow a strict gluten-free diet, avoiding foods and drinks containing gluten, including barley and, consequently, beer. Therefore, a further reduction of the gluten content of beer, below 20 $mg \cdot kg^{-1}$, is needed to use the "gluten-free" claim and to meet the growing demand for gluten-free beers in the market [3, 4].

Unmalted adjuvants are often used in the brewing industry as a cost-effective alternative source of extract, as well as for the individual functionality they bring to the finished beer brewing process. Cost reduction can be determined by minimizing the requirements for the malting process and its associated costs. In addition, cost savings can arise from replacing potentially expensive barley malt with cheaper, locally sourced grains. The choice of unmalted grains in the global industry is thus strongly influenced by local raw material supply and cost considerations. The quality attributes of some of the world's leading beer brands are based on additives used in their recipes. Adjuvants are used by brewers both to modify beer quality (i.e. aroma, foam, colloidal stability) and to enable the production of innovative new products with specific desired characteristics.

Achieving beer with unmalted grains, especially in large quantities, can be challenging, and a more detailed understanding of the factors limiting their incorporation rates into brewing recipes is needed. The reduction in amylolytic, cytolytic, and proteolytic enzyme activity in the mash, these enzyme systems are activated and generated during the malting process, is the biggest problem in terms of processability when including unmalted adjuvants. The actions of these three enzyme systems during malting and saccharification influence the chemical composition of the wort and the efficiency of beer extract recovery. The varied biochemical composition of grain materials will impact both the performance of the brewing process and the quality of the finished beer.

A deficiency in enzyme activity and variations in the composition of unmalted adjuvants can consequently influence the aroma profile of the finished beer [1]. Hence, it should be noted that the addition of any unmalted adjuvant will reduce enzyme potential and increase β-glucan levels. The adjuvant tends to increase the viscosity of the wort and decrease the filtration efficiency [5]. Among the compositional changes that have an impact on the process, the presence of β-glucans and pentosans is the most significant, which can cause viscous wort, slow wort separation, decreased extract recovery, slow filtration and higher filter use [6, 7]. However, such effects on the flavor of the finished beer are not yet fully understood [1].

Using grains that do not have gluten generating proteins during the brewing process is a suitable approach for producing gluten-free beer. Rice, maize, sorghum, millet, teff, pseudocereals such as buckwheat, quinoa and amaranth, have been studied in recent years as alternatives to barley malt in the production of gluten-free beer [6]. In the specialized literature, there are several studies that investigated the production of beer from unmalted grains. Interest in producing beer just from unmalted barley has grown during the past few years [4]. For example, Steiner *et al.* reported that using 100 % unmalted barley produced beer with less fullness and foam stability [8].

The use of buckwheat and sorghum as adjuvants in brewing has been known for a long time. The first concerns in the use of buckwheat in brewing consisted of using it as an unmalted raw material to improve the extract content of beer wort and reduce production costs. This was made possible by adding this pseudocereal during the mashing stage in the form of flour, groats, or extruded food. Buckwheat, however, has a higher nutritional value and yield than maize and wheat, and it also has more resistance to unfavorable climatic conditions than barley and wheat [9].

Buckwheat has proven to be suitable for use as a raw ingredient in brewing, particularly for application in the production of gluten-free beer. Buckwheat malt has low amylolytic activity and low extract yield, low filtration rates related to high wort viscosity, and problems with wort fermentation. Therefore, it is necessary to use additional enzymes to balance the low enzyme activity and allow complete saccharification. Considering the nutritional and sensory characteristics, beers made from 100 % buckwheat malt develop a distinctive nutty aroma, are darker in color and have a lower alcohol content than barley malt beers. Buckwheat is the only pseudocereal that contains rutin, a flavonoid that possesses antioxidant, anti-inflammatory and anti-cancer effects, among others. The use of buckwheat malt in lager brewing has been shown to routinely provide fortified beers. Compared to beers produced exclusively of barley malt, these beers have comparatively strong antioxidant capacity and oxidative stability under forced maturation. Milder conditions during malting support an increase in the total polyphenol composition and, subsequently, the antioxidant activity of beer [10, 11]. Our previous research at the laboratory level led us to the conclusion that beer can be obtained from buckwheat and without it being malted, just by adding enzyme preparations to the brewing [12].

In order to produce all varieties of beer (Ale and Lager), sorghum must be used as a substitute for barley malt. Protein, B vitamins, minerals, fiber, and cholesterol-lowering waxes are all abundant in sorghum, which is also a great source of these nutrients. Regarding unmalted sorghum, it was found that the sensory quality of beer that was obtained with 50 % unmalted sorghum is similar to that of beers obtained from 100 % barley malt, although they have lower foam stabilities [10, 13]. Schnitzenbaumer *et al.* published a study with the synthesized results of two 40 % unmalted sorghum beers (a red and a white variety) and in both cases achieved very similar ratings to the 100 %

barley malt beer in terms of sensory qualities such as aroma, fullness and bitterness [14]. Sorghum, both as malted sorghum and as an adjuvant, has historically been used in Africa as the main raw ingredient in brewing [15, 16]. The availability of sorghum beers on the market demonstrates that the use of this grain in brewing is a possibility. To improve the sensory properties of the finished product, specialized literature recommends using sorghum in combination with other cereals [3, 17, 18].
In our previous studies conducted under laboratory conditions we obtained positive results regarding sorghum beer, results that led us to the conclusion that a finished product can only be obtained from 100 % unmalted sorghum [18].
This paper presents the research carried out to obtain buckwheat and sorghum beer in unmalted form in microbrewery system. Beer - finished product was evaluated from a physico-chemical and sensory point of view.

MATERIALS AND METHODS

Raw materials

Buckwheat cultivated in the NE part of Romania from the 2020 harvest and sorghum cultivated in the eastern part of Romania from the 2021 harvest were used in the experiments. Pilsner type barley malt from Osivo, Slovakia was used for the comparative study. Amarillo Yachima Chief hops from the Yakima, Washington, USA, 2019 harvest, Fermentis brewer's yeast type 74/30, and an enzyme preparation (amylase) from the Novozyme company, named Termamyl Classic, were also utilized to produce the beer under microbrewery system conditions.

Brewing in microbrewery system

Wort production
The wort was obtained in a Brewferm (Belgium) microbrewery equipment. The raw materials were first milled, weighed and transfer to the mashing vessel. 5 kg of raw material and 15 L of mashing water were used to form the mash, according to the variants shown in Table 1.

Table 1. *Variants of manufacturing recipes studied*

Ingredient	Brewing recipe variant			
	CS	B1	B2	B3
Barley malt [%]	100	-	-	-
Unmalted buckwheat [%]	0	100	0	50
Unmalted sorghum [%]	0	0	100	50
Termamyl classic enzyme preparation [%]	-	1	1	1
Initial *p*H of the mash	6.30	6.39	6.68	6.60

The *p*H of the experimental mash was adjusted with concentrated (80 %) lactic acid to 5.50. For all 4 variants of the manufacturing recipe, the mashing process was carried out according to the following schedule: heating the mash to 45 °C and rest it at this temperature for 15 minutes, then the temperature was raised to 65 °C by continuously mixing the mash. After reaching this temperature, the mash was rest for 40 minutes, then it was brought to 72 °C and from this moment, the saccharification rate was determined, with iodine test. At this temperature it was held for 70 minutes, then the temperature of the mash was brought to 78 °C where it was held for 10 minutes. After cooling to 20°C, the mash was subjected to filtration, brewer spent grain obtained was washed with a quantity of 15 L of water to recover the retained extract. The obtained wort was boiled with hops (16 g Amarillo hops (7.8 % alpha bitter acids)/L wort) in the boiling vessel for 1 hour. Following boiling, the wort was cooled to 20 °C, allowed to sit for 30 minutes to allow the cold wort to sediment, and then decanted into fermentation tanks with a 30 L capacity and CO_2 exhaust valves. Before inoculation with yeast the wort was analyzed.

Fermentation and maturation

After cooling to a temperature of 12 °C, the wort was inoculated with 100 g of 74/30 Fermentis yeast type, the quality of which was previously determined using the Nucleocounter YC-100 device, the total number of cells being 24 x 10^8/mL biomass, of which dead cells 1.42 %. The young beer was bottled and given to secondary fermentation and maturation for 28 days at 4 °C in the same industrial refrigerator after the first fermentation took place at a temperature of 12 °C for 6 days, with the possibility of digital regulation.

Methods of analysis

The wort was determined: saccharification rate (EBC 4.5.1), color (EBC 4.7.1), wort pH, primitive extract (EBC 8.3), yield in extract (EBC 4.2), protein content (EBC 4.3.1), soluble nitrogen (EBC 4.9.1), free amino nitrogen in wort (FAN) (EBC 4.10) with Hach Lange DM 6000 spectrophotometer, apparent degree of fermentation (EBC 4.11.2) with Anton Paar Alex densimeter [19]. Three determinations from the same sample were performed in parallel for analysis and the average value was used in this study.
According to the latest versions of Analytica EBC's standard operating procedures, the following physico-chemical tests were carried out on the finished beer: the original extract and density (EBC 9.43.2), the alcohol content (EBC 9.2.1), turbidity, turbidity S25/S0, turbidity S90/S0; EBC 9.29), *p*H (EBC 9.35), CO_2 content (EBC 9.28.3), O_2 content (EBC 9.37.1) [49], energetic value (EBC 9.45) Anton Paar modular DMA meter (Anton Paar Austria 158 GmbH, Graz, Austria), color (EBC 9.6) and bitterness (EBC 9.8) with spectrophotometer Hach Lange DM 6000 (Hach Lange GmbH, Düsseldorf, Germany) [19]. Three determinations from the same sample were performed in parallel for analysis, and the mean value was used in this study.

Sensory Analysis

A panel of 19 semi-trained judges assisted in the sensory evaluation of the beer samples. The beer samples were evaluated on a scale of 1 to 9, with 1 denoting an extreme dislike, 5 indicating neither a like nor a dislike, and 9 indicating an intense like. Each beer sample was assessed on nine various parameters, including its appearance, color, aroma, general flavor, bitterness, carbonation, body, mouthfeel, and acceptability in general. The test was carried out in the Sensory Analysis Laboratory of the Faculty of Food Engineering at "Stefan cel Mare University" in Suceava. The panelists were given glass cups containing about 70 mL of beer samples that were coded with three-digit numbers and served to them in random order at 8 °C. The panelists used unsalted crackers and water to rinse their mouths in between samples to lessen taste transfer. The tasting space and apparatus complied with EBC 13.2 [20].

Statistical Analysis

All analyses were made in triplicate, and the results were presented the mean and the standard deviation. We used a one-way analysis of variance (ANOVA) and the Tukey's HSD test for multiple comparisons to statistically evaluate the data. For P values 0.01 the variations between the means were deemed statistically significant. Using the design of experiment software (DOE) (Design Expert, trial edition, Stat-Ease, Inc., Minneapolis, MN, USA), the data illustrating the fluctuation of beer parameters according to the varied quantities of buckwheat flour and buckwheat malted flour were plotted. The mean value of the sensory data was graphically displayed by the assessors using Microsoft Excel (Microsoft, Redmond, WA, USA). Using the program XLSTAT (version 2020.3.1, Addinsoft, Paris, France), principal component analysis (PCA) was carried out to highlight the correlations and contrasts between sensory and physicochemical parameters of beers and their variability according to these.

RESULTS AND DISCUSSION

The wort obtained after boiling was analyzed from a physico-chemical point of view, the results are presented synthetically in Table 2.

Table 2. *Physico-chemical properties of wort for mashing variants after boiling*

Characteristic	Brewing recipe variant			
	CS	**B1**	**B2**	**B3**
Saccharification rate [minutes]	15±1.00	70±2.00	70±2.00	70±1.00
Extract of Congress wort [°P]	9.80±0.40	10.80±0.50	10.60±0.30	9.90±0.40
Color [EBC units]	6.40±0.10	17.40±0.50	5.86±0.20	12.20±0.10
*p*H	6.10±0.04	6.13±0.05	6.03±0.04	6.14±0.02
Soluble nitrogen [$mg \cdot L^{-1}$]	695.20±0.75	638.00±0.76	196.00±0.54	414.00±0.82
FAN [mg/100 g]	121.35±0.64	82.40±0.48	41.60±0.50	55.00±0.56
Bitterness value [IBU units]	35.10±0.40	34.10±0.20	31.10±0.50	32.10±0.30
Extract yield [% d.w.]	83.10±0.74	63.90±0.58	50.90±0.42	57.60±0.44

From the analysis of the data presented in Table 2, it can be observed that, regarding the extract of Congress wort, the *p*H and the bitterness value of the wort, the differences between the control sample, the wort obtained from 100 % barley malt and the three experimental variants are insignificant. Different values were found for saccharification time, wort color, soluble nitrogen content, free amino nitrogen (FAN) content and final degree of fermentation. Thus, the saccharification time the wort samples obtained for the 3 experimental variants was almost 5 times longer than the saccharification time of the wort obtained from 100 % barley malt. This difference is due to the fact that barley malt possesses the enzyme equipment necessary to solubilize starch in the boiling process compared to the two unmalted raw materials, buckwheat and sorghum, which are used in the 3 working variants.

To facilitate the starch solubilization process, an enzyme preparation was added that was established to be used in these mashing variants by our previous research [18]. The same explanation, of the lack of enzyme equipment suitable for the solubilization of proteins from buckwheat and sorghum, also led to a low content of soluble nitrogen and free amino nitrogen (FAN) in the wort obtained, the lowest content of soluble nitrogen and FAN being recorded for wort resulting from 100 % unmalted sorghum. The insufficiency of nitrogen compounds in the wort complicates the fermentation process, as such the final degree of fermentation is much lower than in the case of the control sample, and finally, the unsolubilized protein substances can also negatively influence the colloidal stability of the beer. The wort color for the 100 % unmalted buckwheat sample was the darkest, and surprisingly, the 100 % unmalted sorghum wort was lighter in color than the control sample.

The wort was cooled to 12 °C before pitching with yeast. Primary fermentation took place for 6 days, after which the young beer was bottled and allowed to mature for 28 days at 4 °C. The finished beer presented the physico-chemical characteristics shown in Table 3. The beers obtained by the 3 variants differ from the control sample in terms of apparent extract, alcohol content, CO_2 content, soluble nitrogen content, free amino nitrogen content and in the two secondary compounds of alcoholic fermentation, diacetyl and pentanedione and energy value, while insignificant differences were observed in color, *p*H, bitter value.

Table 3. *Physico-chemical characteristics of beer final product*

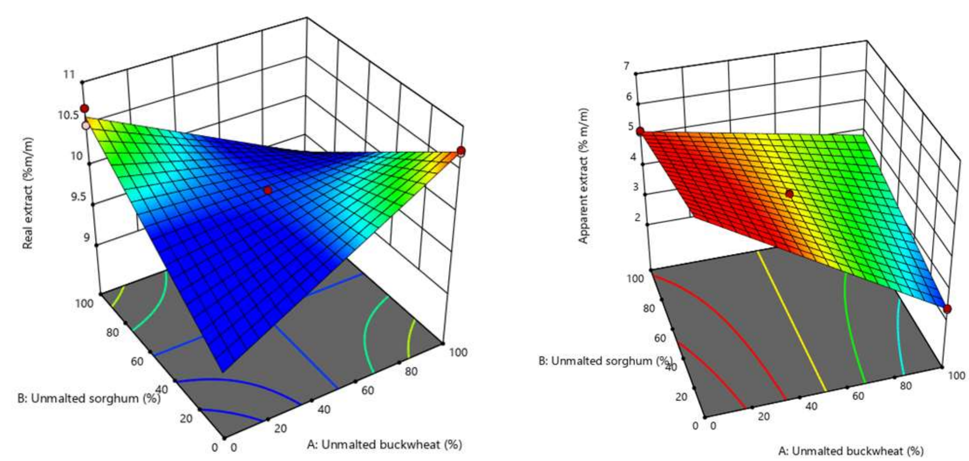
Characteristic	Brewing recipe variant			
	CS	**B1**	**B2**	**B3**
Real extract [% w/w]	10.50±0.20	10.70±0.30	10.50±0.20	9.90±0.40
Apparent extract [% w/w]	2.35±0.04	4.08±0.03	5.15±0.05	4.47±0.06
Alcohol content [% *v/v*]	4.50±0.02	3.51±0.04	2.84±0.04	2.87±0.02
Alcohol content [% w/w]	3.75±0.04	2.73±0.01	2.20±0.02	2.23±0.03
Density [$g\cdot cm^{-3}$]	1.00980±0.0001	1.01481±0.0001	1.01909±0.0002	1.01692±0.0002
Turbidity [EBC units]	2.94±0.02	34.77±0.02	5.23±0.03	9.33±0.01
Turbidity S25/S0 [EBC units]	12.40±0.01	85.93±0.80	15.38±0.04	22.99±0.04
Turbidity S90/S0 [EBC units]	13.62±0.02	61.73±0.02	6.19±0.02	11.73±0.02
*p*H	4.50±0.02	4.86±0.01	4.42±0.05	4.95±0.07
Color [EBC units]	5.20±0.12	7.90±0.50	4.50±0.20	6.50±0.12
Biterness value [IBU units]	19.80±0.40	19.80±0.30	19.30±0.60	19.90±0.62
CO_2 [$g\cdot L^{-1}$]	5.02±0.04	3.13±0.01	3.30±0.01	5.44±0.01
O_2 [$mg\cdot L^{-1}$]	0.11±0.01	1.14±0.02	0.31±0.14	0.39±0.12
FAN [$mg\cdot L^{-1}$]	102.24±0.50	22.80±0.12	4.90±0.02	13.90±0.02
Soluble nitrogen [$mg\cdot L^{-1}$]	234.00±2.10	374.85±1.60	90.16±2.68	230.58±1.80
Diacetyl [$\mu g\cdot L^{-1}$]	45.24±0.24	187.13±0.74	71.68±0.56	233.02±0.70
Pentanedione [$\mu g\cdot L^{-1}$]	28.40±0.62	196.51±0.48	26.55±0.44	129.02±0.40
Apparent extract after fermentation [% w/w]	1.84±0.01	3.20±0.02	4.98±0.02	3.70±0.01
Energetic value [kJ/100 mL]	190.00±2.00	161.95±0.62	159.73±2.60	149.95±0.50

A very important distinguishing parameter is ethyl alcohol, the content of which was affected by the use of unmalted buckwheat and unmalted sorghum. Obtaining different results of this component led to a lower energy value of beer - finished product.

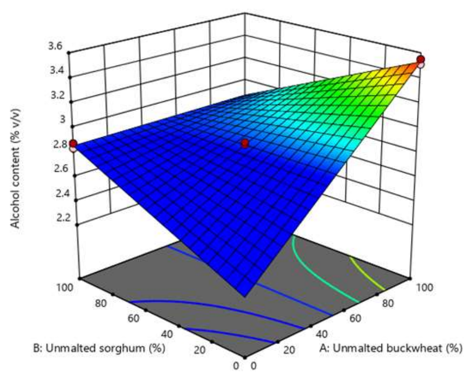
Compared to the control sample, it is observed that the three experimental variants present lower values for alcohol content and free alpha amino nitrogen content (FAN) and close values for the other parameters. The results are consistent with those obtained by Kouakou et *al*. for 100 % unmalted sorghum beer, in terms of alcohol content (2.3 - 3 % alc. v/v), with those obtained by Gasiński et *al*. for the apparent extract value (4.82 - 5.17 % w/w) [21,22].

The sorghum beer also presented the lightest color, which also resulted from the fact that the sorghum wort had the lowest color value. Buckwheat is already known to have sufficient brewing properties to be used as a raw material and has shown substitution potential for barley in the production of bottom-fermented gluten-free beer [23, 24].

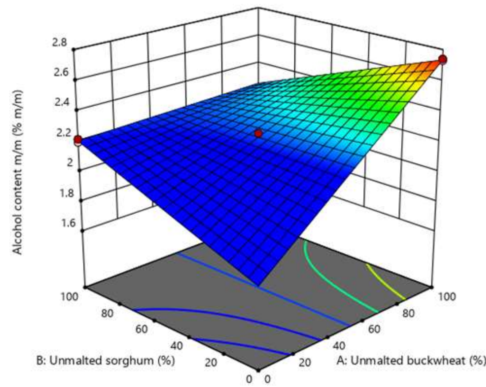
The results obtained for buckwheat beer are close to those obtained by Brasil et *al*. for alcohol content (3.74 % v/v), energy value (160.94 kJ/100 mL), extract content (4.96 % w/w) [25]. Sample 3 obtained from 50 % buckwheat and 50 % sorghum presented physico-chemical characteristics corresponding to a quality beer, a fact that was also confirmed by the sensory analysis performed. This beer presented a lower alcohol content than the control sample, but a higher CO_2 content, a fact also found in the sensory analysis to assess the impregnation with CO_2 and the persistence of the foam. Figure 1 shows the response surfaces for the combined effect of the amount of buckwheat and sorghum on the physico-chemical characteristics of the finished beer.



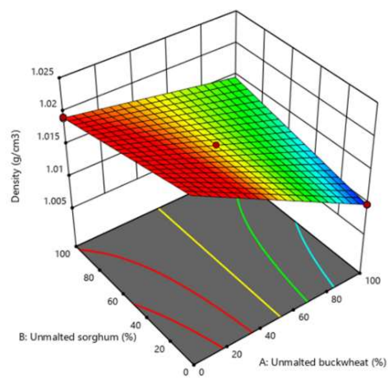
a) **b)**


Alcohol content (% v/v)
B: Unmalted sorghum (%)
A: Unmalted buckwheat (%)

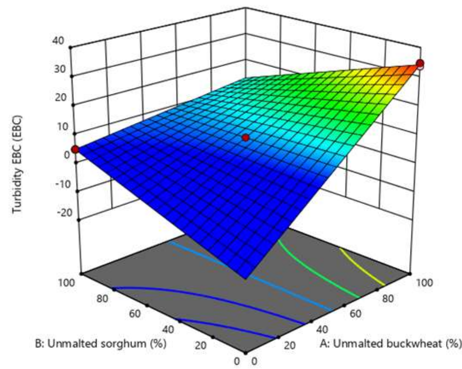
c)


Alcohol content m/m (% m/m)
B: Unmalted sorghum (%)
A: Unmalted buckwheat (%)

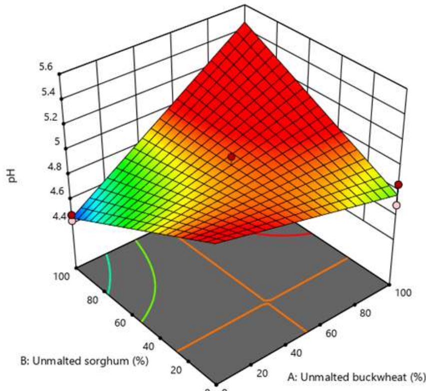
d)


Density (g/cm3)
B: Unmalted sorghum (%)
A: Unmalted buckwheat (%)

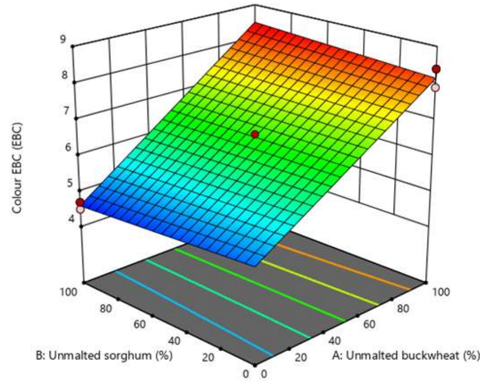
e)


Turbidity EBC (EBC)
B: Unmalted sorghum (%)
A: Unmalted buckwheat (%)

f)


pH
B: Unmalted sorghum (%)
A: Unmalted buckwheat (%)

g)


Colour EBC (EBC)
B: Unmalted sorghum (%)
A: Unmalted buckwheat (%)

h)

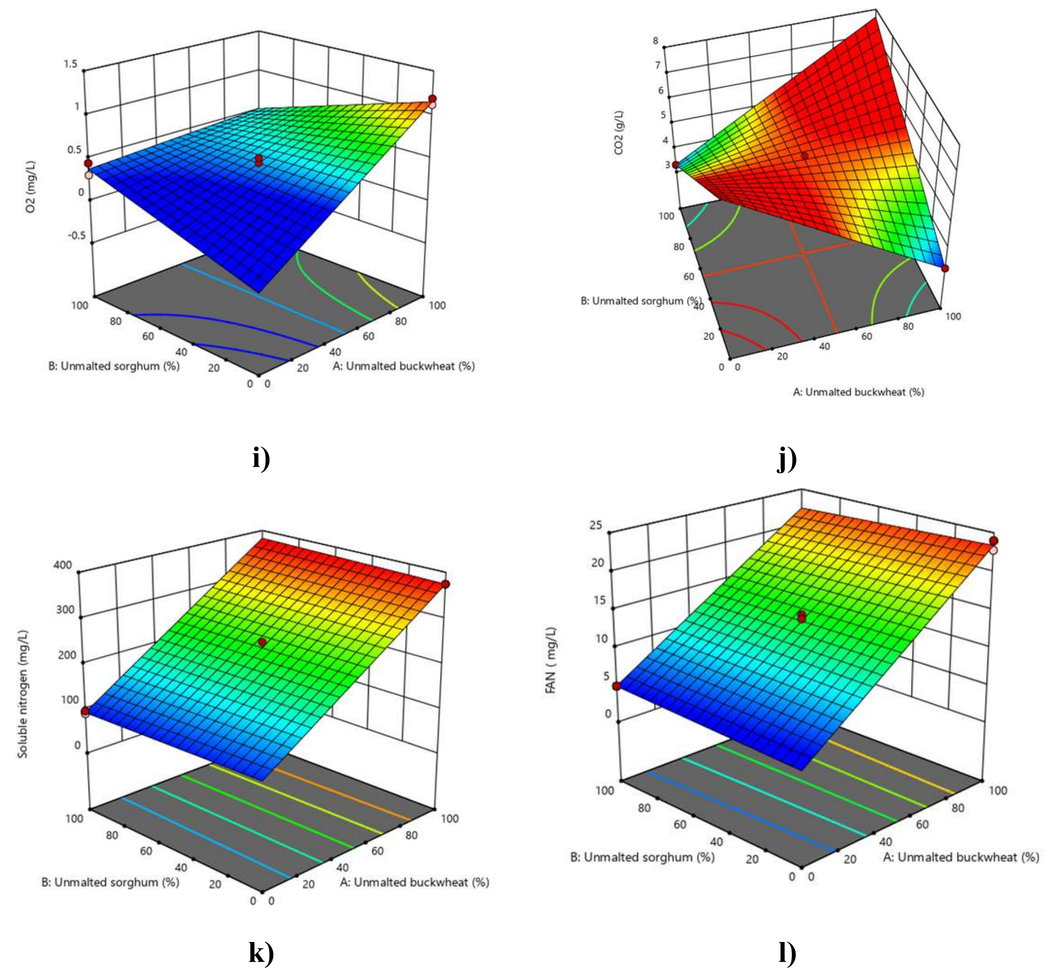


Figure 1. *Graphical representation of the response surface for the combined effect of the amount of buckwheat and sorghum on the physicochemical characteristics of the finished product: a) real extract; b) apparent extract; c) alcohol content (% v/v); d) alcohol content (% m/m); e) density; f) turbidity; g) pH; h) color; i) O_2 content; j) CO_2 content; k) soluble nitrogen; l) FAN*

Sensory analysis results

The condition for a beer to satisfy the minimum quality requirement for sensory analysis is that it must meet a total average score of at least 12.1 points according to the regulations in force. Sensory analysis is an integral part of developing products that meet consumer expectations. Sensory analysis of beer is complex, as more than 800 chemical compounds have been found in beer. To avoid discrepancies and obtain uniform results, panelists are asked to follow the same tasting procedure for each sample [26, 27]. To evaluate the appearance, the foam of the beer, the height of the foam layer, the size and color of the bubbles, the foam that adheres to the glass during consumption and the persistence of the foam must be evaluated. The color and clarity of the beer should also be considered.

The sensory characteristics of the beer samples are shown in Figure 2. Except, color all the sensory characteristics have been most appreciated for the control sample. The lowest scores for beer sensory attributes have been received by B1 sample. Of the non-gluten beers, the most appreciated was the B2 sample. Probably, the sensory qualities of buckwheat and sorghum conducted to a beer well appreciated by the panelists. This data is in agreement with those reported by Owuama (1999) who concluded that a barley malt substitution up to 70 % sorghum may lead to beers with similar sensory properties as beer obtained with only barley malt [28]. According to Owuama (1997) the sorghum lager beer characteristics are comparable with barley malt ones with the higher differences in color, taste and aroma [29]. The color characteristic was the most appreciated for the sorghum beer sample. This may be due to the fact that sorghum kernel pigmentation has more whiteness which lightens the color of the beer [18]. Also, the B2 sample presented the lowest bitterness value which may be due to it sweet taste which may decrease the bitterness value of beer [30].

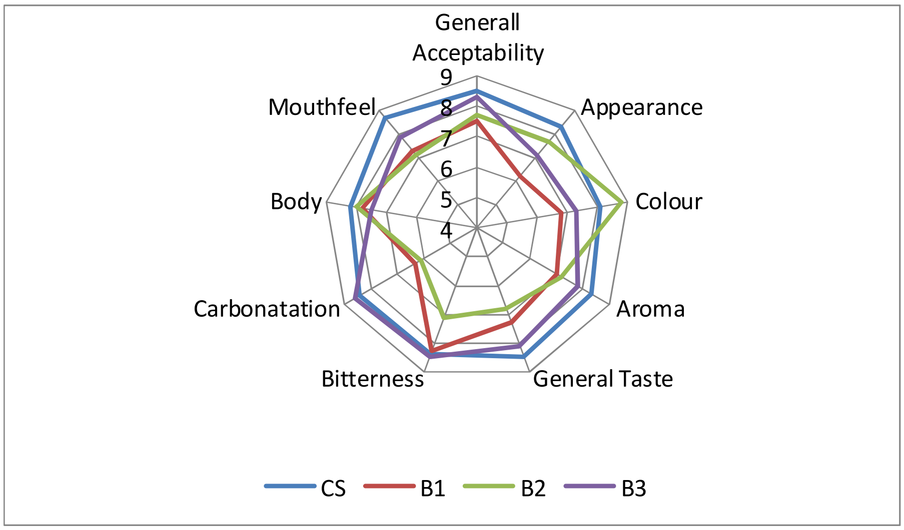


Figure 2. *Sensory analysis of beer samples*

The correlation between the sensory and physico-chemical data for beer samples is shown in Figure 3. The PC1 and PC2 explain 80.05 % of the total variance (PC1 = 45.96 % and PC2 = 34.09 %). The first PC1 is strongly correlated with the beer samples CS, B1 and B2. It seems that B1 and B3 samples are more closely associated, both being placed alongside the PC1 and PC2 axes. The second principal component PC2 underlines an opposition between CS and the beers obtained from unmalted raw materials B1, B2 and B3. The CS are more similar to the sensory characteristics and physicochemical data alcohol content, carbon dioxide and FAN. This association are in agreement with physicochemical and sensory data according to which the CS have been the most sensory appreciated and also presented the highest FAN and alcohol content. The B1 and B3 samples are more related to physicochemical data oxygen, diacetyl, turbidity, pentanedione, *p*H, color and soluble nitrogen while B2 to density, real extract, apparent extract and apparent extract after fermentation. According to Nic Phiaris et *al*., 2010 the beer obtained from buckwheat presented an increase in free amino acids, nitrogen and a high content of polyphenols which may affect its colloidal stability [26]. Also, according to Owuama (1999) beers obtained with high amounts of raw sorghum presents a poor form stability behavior [27]. Almost all the sensory data are closely associated between them. Also, close correlations were obtained between physico-chemical and sensory characteristics. Therefore, a close association was obtained between carbon dioxide and carbonatation (r = 0.989), bitterness and bitterness sensory value (r = 0.996), alcohol content and taste (r = 0.832), etc., correlations that were somehow expected.

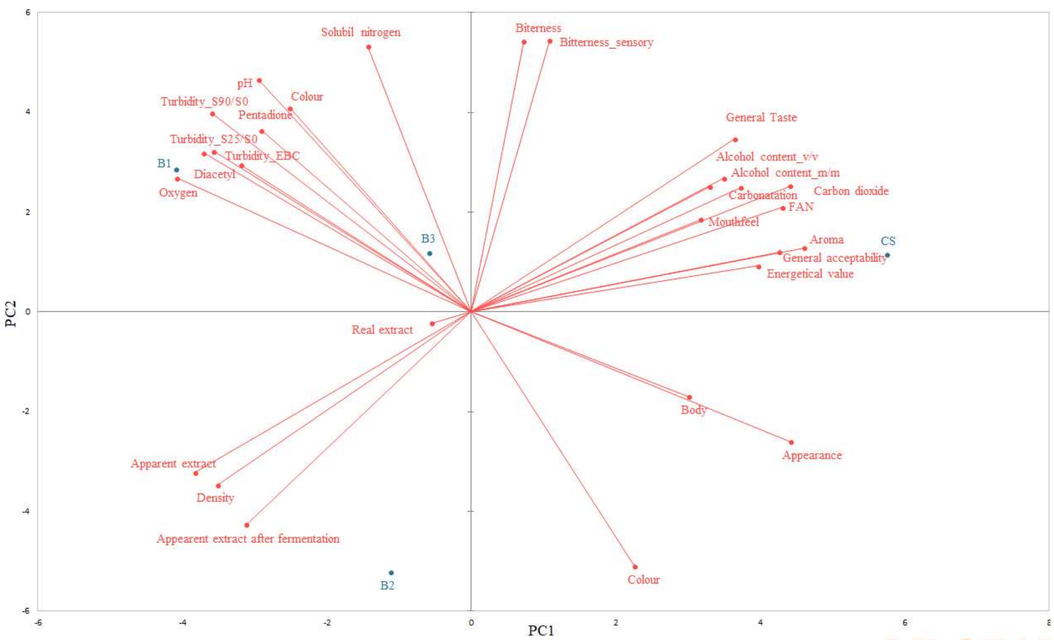


Figure 3. *Principal component analysis of the beer samples and their sensory and physicochemical characteristics*

CONCLUSIONS

Buckwheat and sorghum were used as unmalted grains to obtain, in microbrewery system, beer from 100 % buckwheat or 100 % sorghum and beer from the combination of the two raw materials in different percentages.

The research undertaken demonstrates the real possibilities of using buckwheat and sorghum in the brewing process, from simple adjuvants to obtaining assortments made from 100 % buckwheat or 100 % sorghum.

Through their functional and nutritional characteristics, the two raw materials have thus far demonstrated their abilities to produce finished products that customers value, but they have not yet been fully utilized.

When improving the manufacturing recipe as part of the innovation work done by the specialists, who also take into account the efficacy and efficiency of the manufacturing process for the new beer varieties, the options are practically unlimited.

Through the research carried out, it was aimed to establish an optimal saccharification regime that would lead to a wort with adequate quality characteristics for the efficient obtaining of the finished product.

The optimization of the technological parameters of the saccharification, boiling with hops and fermentation-maturation operations was carried out with the help of the Design

Expert program through the multiple response optimization approach. By using modern optimization methods, the optimal solutions were determined for the key technological parameters in the technological process of obtaining new beer varieties.
The best results in terms of sensory and physico-chemical characteristics were achieved by the beer obtained from 50 % buckwheat flour and 50 % sorghum flour.

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