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Using Extruded Raw Materials in the Production of Beer.

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ABSTRACT

In this paper, an assessment is made on the quality of beer obtained using unmalted raw materials – extrudates of corn and foxtail millet. The use of up to 5 and 10% of grain extrudates made it possible to obtain a light type of beer, which is at the minimum level for this type of beer. Pre-grain corn and foxtail millet were subjected to extrusion processing. Separately, corn and foxtail millet grain was processed in a press extruder at pressures up to 60 atmospheres and temperatures up to 150-200 °C. Such parameters are justified for higher starch hydrolysis. In the process of extrusion starch breaks down into simple sugars, harmful microflora is disinfected. At the same time, the breakdown of protein substances is accompanied by an increase in amino nitrogen. The increase in the content of amino nitrogen leads to more intensive fermentation, the process of fermentation is reduced to 14 days. Extractability increases due to the transition of a larger amount of solids to a soluble state, due to changes in the chemical composition of the native grain, more accessible for hydrolysis. As a result of the research, it was determined that the obtained beer samples prepared using 5% and 10% corn extrudates and foxtail millet as unmalted raw materials differed in comparison with the control sample of beer with increased indicators of real extract, volume fraction of alcohol, actual degree of fermentation, color, content of reducing substances, carbon dioxide saturation, foam height, foam resistance. In terms of organoleptic characteristics, the second sample of beer was prepared using 10% corn extrudates and foxtail millet, differed in a dark amber color, which also corresponded to a light type of beer.
Keywords: barley, extrusion processing, corn, foxtail millet, hops, yeast, quality indicators, hopped wort, beer.

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INTRODUCTION

Heat treatment is one of the most effective and frequently used technological methods that facilitate the preparation of biopolymers of unmalted grain to the technological process of mashing, which can be carried out by various methods, including combined ones. For example, simultaneous exposure to temperature and moisture, temperature, and pressure is possible.

The analysis of modern methods of enhancing the functional and technological properties of grain crops using thermal effects in various sectors of the food and processing industry indicates a significant increase in the interest of researchers in recent years in the process of thermoplastic extrusion [3, 4, 5, 6, 7, 19, 24, 25, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39].

Experimentally, the changes were established in the carbohydrate and protein complexes of extruded barley [8,24,25,26, 31,34, 36]. Destructive changes cause an increase in the enzymatic attack of starch molecules during the preparation of wort, and further contribute to the production of beer with high quality.

In recent years, the volume of brewing malt produced in Russia has increased significantly, but the malt deficit covered by imports is very large [9]. For the purpose of expanding the raw material base of the brewing industry, brewing properties of barley grown in various regions of the Russian Federation are being studied.

After examining some sources of literature, we have seen that malt can be replaced with unmalted starch containing raw materials in amounts up to 50%, including extruded barley [24, 32, 33]. However, when using unmalted materials in an amount of up to 40-50%, it leads to a deterioration in the composition of the wort proteins, an increase in the viscosity of the wort, difficulty in filtering and a decrease in the yield of the extract. By using enzyme preparations, lowering the quality of the wort and beer can be excluded [26].

Unmalted materials are used for the rational use of malt, reducing the cost of production, as well as for expanding the product range of the enterprise.Foxtail millet is an annual plant of the family of cereals (Setariaitalica), food (cereal) and fodder crops. Foxtail millet contains vitamin B1 and B2 in very large ammounts [1,2,21, 23].

Foxtail millet groats contain an average of 1.5% ash. Si, Ca, K, P, F, S, Mg, it is dominated by compounds of silicic and phosphoric acid. Foxtail millet groats are distinguished by a high content of proteins, fat, carbohydrates, possessing a high energy value, and are ranked first among other cereals. Foxtail millet groats contain provitamin A more than millet, is an easily digestible plant product for the human body with a high content of vitamins B1, B2, E [21].

In the Republic of North Ossetia – Alania,foxtail millet is not cultivated. The most widespread and zoned variety of foxtail millet, Stachumi 1, is grown in the neighboring Stavropol region. The variety forms high grain yield is 3.5-4.6 t / ha [2, 23].

Corn (ZeamaysL.) Is an annual plant of the Meadow family. Monoecious, dioecious, cross-pollinating. In the Republic of North Ossetia - Alania, many varieties and hybrids of maize are cultivated. Recently, in the brewing industry, corn is used as a substitute for malt due to the low price and low protein content. If grain is obtained from corn and successfully used, then it can be added in the amount of up to 30% of the mass of all grain products to be mashed [27,28].

Considering that malt contains amylolytic enzymes in its composition, by which saccharification or splitting of starch occurs, as the main property of malt being used in the production of beer, and also without a raw material base for the cultivation of brewing barley, leads to a shortage of raw materials. At the same time, the process of germinating and drying grain is very laborious and requires capital investments. Therefore, it is necessary to purchase expensive raw materials, sometimes even foreign ones.

Therefore, in order to make the rational use of malt, to reduce the cost of production, and also to expand the product range of finished products, it is proposed in our work to replace the malt part with the extruded corn and foxtail millet. The careful literature review conducted by us shows that there is no such work.

The study focused on the use of extruded raw materials in the production of beer. Determination of physical and chemical indicators of the raw materials used, beer wort and beer, as well as the organoleptic analysis of the samples of beer were parts of the research tasks.

MATERIAL AND METHODS

Barley grain, malt, corn grain, foxtail millet grain, corn extrudate, foxtail millet extrudate, hopped beer wort, beer were the objects for research.In barley, malt, corn grain, foxtail millet grain, extruded corn, extruded foxtail millet, hopper wort, beer, all physical and chemical parameters, as well as the organoleptic evaluation of beer samples were determined according to the methods appropriate to the State Standards [20].

The following physico-chemical parameters were determined in barley: mass fraction of dry substances (by drying to constant weight, according to the GOST 13586.5-93 [16]; mass fraction of “raw” protein (by Kjeldahl method); mass fraction of “raw” fat (by the gravimetric method according to GOST 26183 [17]); mass fraction of “raw” ash (by the gravimetric method according to GOST 26929); mass fraction of “raw” fiber, mass fraction of nitrogen-free extractive substances (the NES calculation method).

Pre-grain barley was soaked to produce malt. Soaking was carried out in water at the temperature of 14-16 °C for 25-30 hours. The germination of the grain occurred at a temperature of 16-18°C for 4-5 days. Dried freshly sprouted malt at 75 °C for 24 hours to a moisture content of 5-7% [22]. The ability of germination according to the GOST 10968-88 was determined in barley [11]. In barley and malt, the mass fraction of starch was also determined according to the GOST 10845-76 (using the polarized Evers method) [10].

The following physico-chemical parameters were determined in malt, in maize grain, in foxtail millet grain, in extruded maize, in extruded foxtail millet: mass fraction of dry substances by the method of drying to constant weight according to the GOST 13586.5-93 [16]; the mass fraction of sugars by the Bertrand permanganate method; the mass fraction of starch by the polarization method according to Evers [10]; the mass fraction of protein according to Kyeldal; the mass fraction of fat by the gravity method according to the GOST 26183 [17]; the mass fraction of fiber by the gravimetric method, extractiveness (by the gravimetric method, according to the GOST 12136-77 [12]; the content of amino nitrogen by the titrimetric method [20, 22].

The following physico-chemical parameters were determined in beer hopper wort: the mass fraction of dry substances (by the refractometric method); chromaticity (according to the GOST 12789-87 [14]); acidity by the titrimetric method (according to the GOST 12788-87 [15]); sugars (glucose + maltose) by the permanganate method; polyphenols by colorimetric method, the final degree of digestion pycnometric method [20].

The following physico-chemical parameters were determined in the finished beer: the extract is valid according to the GOST 12787-81 [13]; the alcohol volume fraction according to the GOST 12787-81 [13]; the actual degree of fermentation in accordance with the GOST 12787-81 [13]; reducing substances by the permanganate method; chromaticity according to the GOST 12789-87 [15]; polyphenols, carbon dioxide saturation, foam height, foam resistance according to G.A. Ermolaeva [20].

The finished beer was subjected to organoleptic analysis [20]. Malt was prepared from barley grain in the laboratory. Malt was crushed to a flour content of 29%. In the control experiment, malt with water was mixed in a ratio of 1:4. In the first and second variants, the raw material was mixed with water in the same ratio. Malt must comply with the requirements of the GOST 29294-92 [18].

Pre-corn and foxtail millet grain was subjected to extrusion processing. Corn and foxtail millet grain was separately filed for processing in a press extruder. In screw extruder working bodies, the grain is subjected to a short-term, but very intense mechanical and barothermal effect. The grain was processed in a press extruder at pressures up to 60 atmospheres and temperatures up to 150-200 °C. Such parameters are justified for higher starch hydrolysis. After that, the expanded, porous product in the form of a rope (strands) comes out of the extruder press with a diameter of 20-30 mm, with a bulk weight of 100-120 g / dm^3 and humidity of 7-9%. We used the extruder “Expro 02", press extruder.

For the first and second variants of the experiments, grinding was used to prepare the corn extrudate and foxtail millet grains with the passage of particles of the studied raw material through a sieve with openings with a diameter of 1 mm (95-98%).

As a result of laboratory experiments, granulated hops were taken from the Vladikavkaz beer and soft drinks plant (VBSDP) “Daryal”, including the Magnum hops (with humidity of 10.1%, total resin content of 17.3%, soft resin content of 14.9%, including bitter α-acids 6.8%, β-fraction of 8.1%, solid resins of 2.4%, tannins of 4.6%, effective bitter substances - 15.6%, granular, dark green).

The groundwater yeast of 4/70 race of the species *Saccharomycescerevisiae* was used to make beer.The variants of the experiments included: the control version – malt (1 kg), hops (16 g), water (4 l), yeast (170 g);the first option includes 90% malt (900 g) + 5% extruded corn (50 g) + 5% foxtail millet grinding (50 g), water (4 l), hops (16 g), yeast (170 g);the second option includes 80% malt (800 g) + 10% extruded corn (100 g) + 10% foxtail millet grinding (100 g), water (4 l), hops (16 g), yeast (170 g).

RESULTS AND DISCUSSION

We pre-assessed the quality of barley. Mass fraction of dry substances in barley grain was 87.0%, which included: mass fraction of protein – 10.65%, mass fraction of fat – 3.0%, mass fraction of ash – 1.8%, mass fraction of fiber – 10, 2%, mass fraction of nitrogen-free extractive substances – 74.35% (Table 1).

Table 1: Physical and chemical indicators of barley grain taken to produce malt

Indicators	Barley
Mass fraction of dry substances, %	87,0
Mass fraction of “raw” protein, %	10,65
Mass fraction of “raw” fat, %	3,0
Mass fraction of “raw” ash, %	1,8
Mass fraction of “raw” fiber, %	10,2
Mass fraction of nitrogen-free extractive substances, %	74,35

Next, to obtain malt, barley was soaked. We determined its ability to germinate, which amounted to 95.0%. The starch content in malt reached 54.15%, in barley – 55.0%. At the same time, the mass fraction of proteins in malt was 9.75%, extract content - 79.65%.

Physical and chemical indicators of the raw materials used, before and after processing on an extruder, are presented in table 2. According to table 2, the mass fraction of moisture in the corn extrudate and foxtail millet is 8.0%, in malt - 3.8%. Mass fraction of protein in corn extrudate was equal - 9.12%, in foxtail millet extrudate - 10.12%, in malt - 9.75%. The fat content in the corn extrudate was 1.0%, in the foxtail millet extrudate 0.8%, and also in malt 0.8%. The mass fraction of cellulose in the corn extrudate was 1.2%, and in the foxtail millet extrudate it was 3.8%. The content of amino nitrogen in malt was - 35.8 mg / 100 g, in the corn extrudate - 48.5 mg / 100 g, in the foxtail millet extrudate - 59.8 mg / 100 g (Table 2).

In the process of extrusion starch breaks down into simple sugars, harmful microflora is disinfected. In malt, the mass fraction of sugars was noted – 1.4%, in the corn extrudate – 1.8%, in the foxtail millet extrudate - 2.0%. Mass fraction of starch in malt was – 54.15%, in corn extrudate – 46.0%, in foxtail millet– 50.75%. Extraction in malt was minimal and amounted to 79.65%, the average amount in the corn extrudate was 81.28%, and the maximum extract content was noted in the foxtail millet extrudate – 85.08% (Table 2).

The decrease in the mass fraction of moisture, protein, fat, fiber, sugars, starch in extrudates in comparison with the indicators of natural grain was observed due to the effects of high temperature and pressure. The increase in the content of amino nitrogen, extract content in extrudates is also explained by the effect of barothermal treatment. It should be noted that the increased content of amino nitrogen will favorably affect the fermentation process. Extractability increases due to the transition of a larger amount of solids to a soluble state, due to changes in the chemical composition of the native grain, more accessible for hydrolysis.

Table 2: Physical and chemical indicators of the raw materials used before and after processing on the extruder

Indicators	Malt - control	Raw materials, before and after processing on the extruder			
		Corn	Corn extrudate	Foxtail millet	Foxtail millet extrudate
Moisture content, %	3,8	13,86	8,0	14,0	8,0
Mass fraction of protein, %	9,75	10,18	9,12	11,26	10,12
Mass fraction of fat, %	0,8	3,0	1,0	2,5	0,8
Mass fraction of fiber, %	1,2	2,8	1,2	7,0	3,8
Amino nitrogen content, mg / 100 g	35,8	40,5	48,5	51,9	59,8
Mass fraction of sugars, %	1,4	2,5	1,8	3,0	2,0
Mass fraction of starch, %	54,15	58,0	46,0	62,4	50,75
Extract,% (dry basis)	79,65	79,85	81,28	83,22	85,08

In all variants of the experiment, mashing was performed by a single-batch method. To prepare the mash,we took malt, filled it with 45 °C waterin the ratio 1:4. Then the temperature was raised to 50 °C, paused for 30 minutes. Then heated to 63 °C and paused for 20 minutes. After that, 1/3 of the mash (1 L) was taken to another tank, in which the temperature was raised to 70 ° C and then boiled for 15 minutes. After that, the decoction was connected to the main mash mass. At a temperature of 73°C, it was kept until the complete saccharification and then filed for filtration.

The wort hopping was carried out according to a single scheme: the total duration of boiling the wort with hops was 120 minutes, 70% of the hops were introduced at the beginning of boiling, 20% – 30 minutes before the end of boiling and 10% – 10 minutes before the end of boiling.

The wort fermentation was carried out in the classical way, using the yeast of the 4/70 race. The main fermentation proceeded for 7 days at a temperature of 9-10 °C, maturation for 21 days at a temperature of 0-2 °C. Next, this beer was filed for filtering. In the process of making the beer, the fermentation period was reduced to 14 days [20].

The mass fraction of dry substances in all variants of the experiments was noted in the range of 11.0-11.5% (Table 3).

Table 3: Physico-chemical indicators of the hopped wort

Indicators	Control	Variant -1	Variant - 2
Mass fraction of dry substances, %	11,0	11,2	11,5
Color, ml 0.1 n. I_2/ 100 ml	0,68	0,72	0,88
Acidity, ml 0.1 n. NaOH / 100 ml	1,52	1,72	1,82
Sugar (glucose + maltose), g / 100 g	5,26	5,42	5,68
Polyphenols, mg / 100 g	15,5	18,0	18,5
The final degree of fermentation, %	76,2	78,4	79,4

According to the data in Table 3, in the control variant, the mass fraction of dry substances are the smallest (11.0%), medium (up to 11.2%) in the first variant of the wort, and the largest is up to 11.5% in the second variant of the wort.

The color, determined visually, was higher in the second variant of the experiment (0.88 ml 0.1 n. I2/100 ml, that is, when replacing the part of the malt in 10% of corn extrudates and foxtail millet, respectively), compared with the control variant (0.68 ml 0.1 n. I2/ / 100 ml) 0.2 ml more. In the first variant of the experiment (when replacing a part of malt with 5% corn extrudates and foxtail millet, respectively), the color of the hopped wort is 0.72 ml 0.1 n, I2/100 ml in comparison with the control (0.68 ml 0.1 n. I2/100 ml). The hopped wort acidity is also greater in the second embodiment, up to 1.82 ml 0.1 n. NaOH / 100 ml, in the first embodiment, up to 1.72 ml 0.1 n. NaOH / 100 ml, in the control variant – 1.52 ml 0.1 n. NaOH / 100 ml. The sugar content in the wort is highest in the second variant up to 5.68 g / 100 g, the average – in the first variant of the experiment up to 5.42 g / 100 g and the minimum in the control variant up to 5.26 g / 100 g (Table 3). The increased chromaticity and acidity in the second variant can be explained by the influence of the foxtail millet extrudate.

The minimum amount of polyphenols is also contained in the control variant of the experiment up to 15.5 mg / 100 g, in the other two variants the content of polyphenols ranges from 18.0 to 18.5 mg / 100 g. In all variants, the final degree of fermentation of hopped wort is from 76.2 to 79.4%. The maximum final degree of digestion in the second variant of the obtained wort can be explained by the high content of amino nitrogen in the extrusion of foxtail millet.

Thus, in the first and second prototypes of hopped wort, the highest indicators of chromaticity, acidity, sugars, polyphenols and the final degree of fermentation were obtained, compared to the indicators of the control variant of hopped wort.

The actual extract in all samples of beer was noted in the range from 4.3 to 4.8% (Table 4).

According to Table 4, the obtained beer samples were prepared using 5% and 10% extrudates of corn and foxtail millet as unmalted raw materials, in comparison with the control sample of beer, were distinguished by high rates of real extract, volume fraction of alcohol, actual degree of fermentation, color, content of reducing substances, carbon dioxide saturation, foam height, foam resistance.

Table 4: Physical and chemical indicators of the finished beer

Indicators	Control	Variant -1	Variant - 2
Extract valid, %	4,3	4,5	4,8
Volume fraction of alcohol, %	3,6	4,0	4,5
The actual degree of fermentation, %	53,5	55,5	56,5
Color, ml 0.1 n. I_2/100 ml	0,58	0,62	0,78
Reducing substances, g / 100 g	0,85	0,90	0,93
Polyphenols, mg / 100 g	13,2	15,0	15,2
CO_2 saturation, %	0,46	0,47	0,47
Foam height, cm	3,5	4,0	4,0
Foam resistance, min	3,5	4,0	4,0

The organoleptic analysis of all three beer samples was carried out according to transparency, color, aroma, taste, height of foam, and saturation with carbon dioxide (Table 5).

Beer in the control version was transparent with glitter and had no suspensions, which corresponds to a light type of beer. It is at the minimum level for this type of beer (amber), with a fresh pronounced aroma corresponding to this type of beer, with a harmonious taste corresponding to this type of beer with pure hop, soft bitterness, with abundant, compact foam, resistant to 3.5 cm, durability 3.5 minutes with abundant, and slow gas bubbles.

The first beer was also different in amber color, height of foam and its durability (4.0 cm and 4.0 min, respectively). The second sample of beer differed from the control, and the first samples had a dark amber color. This can be explained by the 10% addition of foxtail millet extrudate. All samples of beer obtained as a result of research had 25 points on the tasting assessment.

Table 5: Organoleptic evaluation of beer samples

Indicators	Control	Variant 1	Variant 2
Transparency	Transparent with shine, without suspensions (3 points)	Transparent with shine, without suspensions (3 points)	Transparent with shine, without suspensions (3 points)
Color	Corresponds to the light type of beer, is at the minimum level for this type of beer (amber color) (3 points)	Corresponds to the light type of beer, is at the minimum level for this type of beer (amber color) (3 points)	Corresponds to the light type of beer, is at the minimum level for this type of beer (dark amber color) (3 points)
Aroma	Fresh, pronounced aroma corresponding to this type of beer (4 points)	Fresh, pronounced aroma corresponding to this type of beer (4 points)	Fresh, pronounced aroma corresponding to this type of beer (4 points)
Taste	Harmonious, corresponding to this type of beer (5 points) with purely hop, soft bitterness (5 points)	Harmonious, corresponding to this type of beer (5 points) with purely hop, soft bitterness (5 points)	Harmonious, corresponding to this type of beer (5 points) with purely hop, soft bitterness (5 points)
Foam and carbon dioxide saturation	Abundant, compact, resistant to a height of 3.5 cm, resistance to 3.5 minutes with abundant and slow release of gas bubbles (5 points)	Abundant, compact, resistant to a height of 4.0 cm, with a resistance of 4.0 minutes with abundant and slow release of gas bubbles (5 points)	Abundant, compact, resistant to a height of 4.0 cm, with a resistance of 4.0 minutes with abundant and slow release of gas bubbles (5 points)

In terms of physical and chemical parameters, the obtained beer samples in the first and second versions meet the requirements of GOST standards. According to organoleptic assessment, they correspond to the light type of beer, they are at the minimum level for this type of beer.

CONCLUSION

1. For the production of light-type beer using raw materials, up to 10% of corn and foxtail millet extrudate can be used.
2. In terms of physico-chemical parameters, the obtained beer samples meet the GOST requirements (a state quality certification system in Russia).
3. According to the organoleptic assessment, the obtained beer samples correspond to the light type of beer are at the minimum level for this type of beer.
4. It is recommended in the production of beer to use extruded raw materials as raw material. As the degree of hydrolysis of starch increases, the degree of dissolution of sugars increases, the content of amino nitrogen increases, and the period of fermentation is reduced to 14 days.

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