IMPROVEMENT OF LOCALLY MANUFACTURED EQUIPMENT FOR NON-STANDARD OAT PROCESSING

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Abstract: Analysis of the existing oat groat and Hercules flakes production processes suggests that oat processing technology largely corresponds to the conventional technologies prescribed in the applicable regulatory documentation. This process only allows for processing oat grains which conform to standard specifications. Use of off-spec grain results in production of low grade or non-conformant products, which considerably reduces the profit margin of such processing. This paper presents results of studies on non-standard oat grains processing. This grain differs from standard type in moisture content, in mass fraction of double grains, in mass fraction of small grains, and in grain admixture content (grain mixtures). A distinctive feature of the technologies we propose is the lack of this grain preparation stage preceeding the processing part. Use of the proposed technologies allows to increase both utilization and profitability of oat processing and groat production facilities. Our findings suggest that the proposed technologies provide considerable advantages. We have calculated the economic effectiveness of processing grains with four types of non-conformity. We demonstrated that use of this technology allows to reduce production costs of non-standard grain processing in producing Hercules oat flakes by up to 17.8% and result in a fully conformant product.

Keywords: oat grain, humidity, small grain, double grains, substandard grain, Hercules flakes, small grains, grain properties

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INTRODUCTION

Grain products belong to the staple food due to their distinctive features: capacity to synthesize a great number of dry substances, to retain their properties for a long period of time, their transportability and affordability. With their significant nutritive value – proteins, carbs, minerals, and vitamins they contain – grain derivatives account for approximately 1/3 of the human diet, providing for more than half of the daily energy intake [1].

Use of oats in food industry (oat groats, flakes, flour, oatmeal, etc.) is related to high digestibility of its nutritional elements and vitamins; diverse benefits of oats make this product equally suitable for healthy people, individuals suffering from diabetes and hypertension, for kids and people with specific dietary needs. Oat derivatives consumption is on the third place after rice and buckwheat, and keeps growing constantly.

However, flour & groats industry of Altai Krai is faced with a series of systemic challeges, such as [2]:

– Shortage of quality grain, with specifications complying with groats production codes;

– Considerable wear of process equipment;

– Dwindling markets: recently, Altai Krai has been very active in developing local production, however, Altai groats are not really in demand in the European part of the country;

– Low profit margin does not allow to invest in efficient advertising and marketing campaigns;

– Altai enterprises have no export opportunities;

– Storage, transportation, and logistics for groats products is underdeveloped: rehabilitation and startup of new facilities allows for utilization of max. 45.6% of the total production capacity of groats industry [3].

Low utilization rates of oat grain processing facilities result in use of substandard grains (grains that do not comply with code specifications) for groats production. In the last 12 years, work experience of Biyskiy elevator JSC, located in the Biysk region of Altai Krai, showed that the quantity of such substandard grain might reach up to 50%. Grain processing companies face the shortage of quality grain suitable for groat production. New grain processing methods and technologies are being elaborted in order to address the challenge of processing poor quality grains. Due to low cost-efficiency of such processing, this type of grain had always been used as forage, and never in food industry applications.

New technological solutions are being designed in order to respond to such objectives as production costs and price reduction, product quality improvement, higher utilization efficiency for grain and grain derivatives, development of cost-effective equipment and resource-saving grain processing technologies, elaboration of a new series of healthy food products with targeted modifications introduced into their chemical composition [4].

Production process taking place at an oat processing facility consists of a series of interrelated operations, each one of them is performed by designated equipment and corresponds to the specific anatomy of a grain, with respective distribution of nutrient and non-nutrient substances within. Analysis of the existing groat production processes suggests that groat processing technology largely corresponds to the conventional classifications prescribed in the applicable regulatory documentation.

This technology only allows to process the grain that conforms with the code specifications. Results of non-standard grain processing allow to conclude that grains with off-spec quality undergo a significant change of their technological properties. That is why processing such grain with the help of standard technology results not efficient or altogether impossible.

Use of non-standard grain leads to deficient production output and low profit margins. Therefore, it seems reasonable to investigate quality parameters and technological properties of non-standard grain, which will contribute to a better organization of technological processes for obtaining groat from this grain.

As of today, no data have been reported on rehabilitation of assemblies and equipment targeting non-standard grain to groat processing.

The objective of this work is to improve home-made equipment for processing non-standard oat grains, and to evaluate the efficiency of the proposed technological solutions.

OBJECTS AND METHODS OF STUDY

For our experiments, we selected batches of non-standard oat grains grown in the Biysk region of Altai Krai between 2002 and 2014 and delivered for oat flour processing to be further distributed via retail and wholsale.

All studies were carried out in shop conditions, at an oat processing facility with 50.0 ton/hour capacity. We used grains of spec quality, complying with groat processing code requirements, as controls.

Cost efficiency of a grain processing facility depends on various factors, including end product output. End product output, in turn, depends on quality parameters of the grain, its moisture content, kernel content, weedy and grain admixtures, uniformity, shape and size of the grain. Grains with the above parameters below the specification requirements are classified as non-standard. Struggling to meet specification requirements in preparing such grains for processing is rather difficult and not really cost effective. Processing such grains for groat results in off-spec products, or products of low quality, with poor nutritional value and taste qualities, which makes these products hardly competitive on the market. However, in market conditions, competitive success of a product is mainly determined by its quality.

In our study, we focused on oat grain batches delivered for processing with the following non-conformities:

– With moisture content of 15.6–18.0%;
– With double grains mass fraction up to 10.0%;
– With small grains mass fraction up to 20.0%;
– Oat admixtures.

RESULTS AND DISCUSSION

Groat quality parameters and profit margin of a processing facility are positively related to the technology used for grain processing, and for the quality parameters of the grain in use. Analysis of current technologies suggests that the existing oat grain processing technologies are based on prior conditioning of the grain until it meets the process requirements. A distinctive feature of the technologies we propose is the lack of this grain preparation stage preceeding the processing part. Implementation of the proposed technologies would allow to use non-standard oat grains in producing oat flour, to ensure certain profit margin for the industry, to reduce production costs and the price of the product, to improve the quality of the product, and to make a rational use of the grains with non-conformities under consideration. As a quantitative analysis, we provide an analysis of product costs for end product calculated in accordance with the technology recommended by applicable codes and standards. All studies were replicated 4-6 times and statistically processed. Across this text, average values are provided for each parameter. To determine these parameters, standard research methods were used.

Processing grain with moisture content above 15.6%. In order to investigate opportunities for improving oat grain processing technology and to adjust it for grains with higher moisture content, we tested a new method based on reduced grain preparation time prior to processing grains into groat and flakes [5].

Of all the grain delivered for processing, batches with moisture content over 15.6% were selected (deviation range 1.0 % max.). These batches were sent directly to the oat processing facility, without prior drying process. Instead of drying the grain until moisture content reaches 13.0–13.5%, in this method we used steaming [6].

According to the proposed technology, oat grains with higher moisture content are supplied into a steaming unit A9-BPB, intermittently operated. Prior to steaming, the grains are pre-heated for 20 minutes up to 20–30ºC, which accelerates the hydrothermal treatment process of the grains. Steaming is performed at 0.2–0.3 MPa pressure for 1.5–3.0 minutes. Steaming duration is calculated from the moment steam is supplied to the steamer until steam supply is stopped. From the steamer, grains are fed into a dryer for 30–40 minutes, with drying agent at 60–90ºC, and dried until the moisture content of 16–18%, then for the next 60–80 minutes they are dried in presence of drying agent at 90–110ºC. Upon drying, grains are cooled with air, down to maximum temperature of 45ºC. When steaming and drying up to 13.0–13.5% moisture content is over, oat grains are fed into a hulling machine with further groats grading and production of Hercules oat flakes.

In order to ensure maximum separation of entire kernels, we need to account for technological properties of the grain, including structural mechanic and morphological ones [7]. Surface morphology was studied for kernels with different moisture content. Moisture content of the grain samples under study is provided in Table 1.

Kernel surface morphology in test samples was studied on a scanning electron microscope JSM-840 (Jeol, Japan), images are presented in Fig. 1.

Microphotographies in Fig. 1b, 1c, 1d allow to discern hairs of various size located across the entire surface; these might make up to 1.5–2.0% of solid mass fraction.

As we can see in Fig. 1, at ×500 magnification, the kernel surface demonstrates a regular pattern seen as longitudinal ribbing, and this pattern is more pronounced when the kernel is dry. Modification of oat kernel surface structure suggests that increased moisture produces changes in its plastic properties, which should lead to a lower hulling factor of the oat.

The grain we used for testing the proposed technology had the following quality parameters (Table 2).

Provided data suggest that grain with higher moisture content might be used for groat production, if the proposed technology is applied.

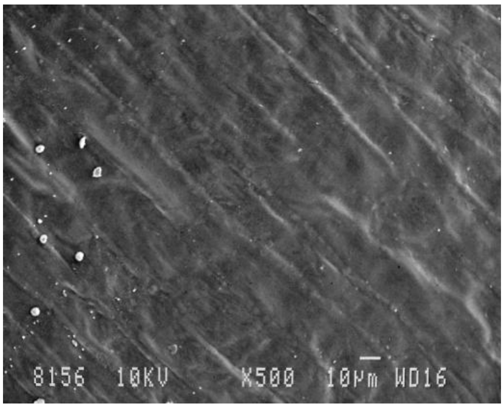
During long storage, Hercules oat flakes are known to undergo changes of both organoleptic and biochemical parameters, which results in overal deterioration of their quality. In order to evaluate changes in acidity and acidity index associated with storage duration, we performed a comparative analysis of these parameters in products manufactured by conventionally recommended and proposed hydrothermal treatment (HTT) technologies [8], results are provided in Table 3

Analysis of the data presented in Table 3 suggests that increasing temperature and pressure of saturated steam used for HTT of oats grain has impact on quality parameters of the end products. Indicated HTT regimes [9] allow for processing grains with the proposed technology, with drying substituted for steaming, which stabilizes acidity modification both in the grain and in the end product.

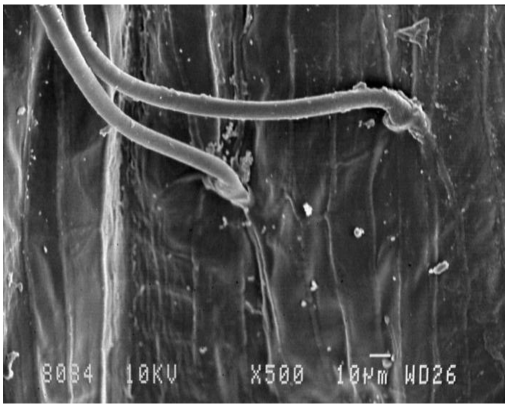
Studies of relationship between acidity / acidity index of end products (Hercules oat flakes) and initial moisture content of grains processed as per the proposed technology, within the guaranteed shelf-life period, and organoleptic properties in accordance with standard requirements, are summarized in Table 4.

Table 1. Kernel moisture content in test oat samples

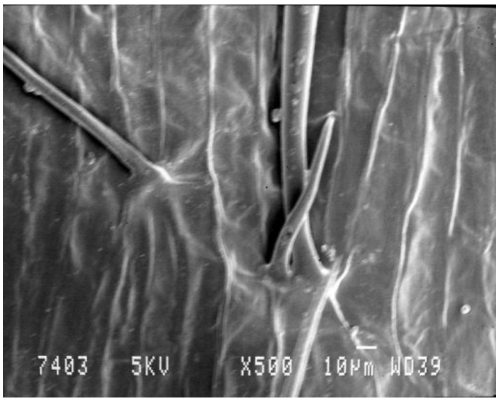
Description	Moisture content by weight, %
Sample 1a	26.7
Sample 1b	17.8
Sample 1c	12.8
Sample 1d	11.4



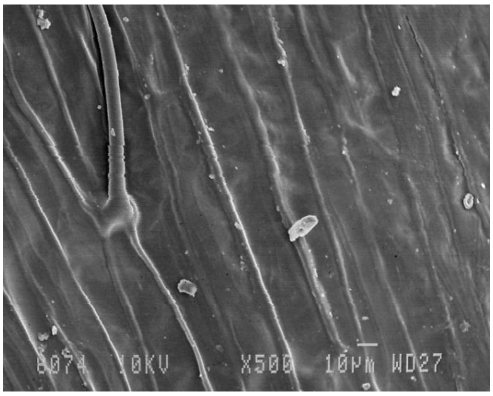
Sample 1a



Sample 1b



Sample 1c



Sample 1d

Fig. 1. Kernel surface morphology in oats with different moisture content ×500.

Table 2. Grain quality parameters in grain processed into groats with conventional and proposed technologies

Parameters	Grain quality		
	as per standard requirements	as per process specifications according to the applicable codes and standards	as per proposed technology
Moisture content, %	max. 13.5	12.5	16.8
Kernel, %	min. 63.0	64.1	63.9
Weedy admixture, %	max. 3.0	2.0	2.5
Grain admixture, %	max. 7.0	4.5	5.4
Acidity, deg.	max. 6.0	5.3	5.4

Table 3. HTT impact on shelf-life changes in acidity and acidity index of Hercules oat flakes

Saturated steam parameters		Acidity, deg.		Acidity index, mg KOH/g	
Pressure, MPa	Temperature, ºC	HTT as per standard requirements	HTT as per proposed method	HTT as per standard requirements	HTT as per proposed method
0.030 ± 0.001	81.0 ± 1.0	5.0–5.5	not determined	16.6	not determined
0.055 ± 0.001	91.0 ± 1.0	5.0–5.4		16.2	
0.070 ± 0.001	99.0 ± 1.0	4.8–5.1		16.1	
0.200 ± 0.001	120.0 ± 1.0	not determined	4.5–4.9	not determined	15.8
0.300 ± 0.001	133.0 ± 1.0		4.4–4.8		15.6

Table 4. Acidity and acidity index changes in Hercules oat flakes during shelf-life period

Parameters	Shelf-life, days								
	30			90			120		
	moisture content of feedstock grain, %								
	below 13.5	14.5	16.3	below 13.5	14.5	16.3	below 13.5	14.5	16.3
Hercules flakes moisture content, %	max. 11.3–11.8								
Acidity index, mg KOH/g	15.8	16.1	16.5	16.3	16.8	17.1	30.6	30.8	31.2
Hercules flakes acidity, deg.	3.2	3.2	3.4	4.0	4.0	4.2	4.9	5.3	5.4
Organoleptic parameters: taste, color, odor	conform to the standard, characteristic								

Analysis of the above Table 4 suggests that within the indicated period, Hercules oat flakes produced by the proposed technology are in conformity with the standard requirements.

Designing a processing technology for oat grains with double grains mass fraction below 10 %. In processing oat grains delivered to the plant we selected batches with high content of double grains [10]. When grains are processed into groats, groat feedstock is quality oat suitable for groat production. Most important traits of grains suitable for groat production are a well formed kernel with minimum hull content. According to the standard requirements, oat grains shall be uniform in size, and contain a minimum amount of double grains which are difficult to process.

Double oat grains are formed in a two floret spikelet with an undeveloped or underdeveloped kernel of the first floret, under unfavorable flowering conditions in dry years. The lower grain of the spikelet is not developed or only partially developed, and its hulls are covering the second grain. Oat kernel has an elongated spindle-like or oblong shape, and the hull is tight.

Quality parameters of double grains in comparison to average quality of oats grown in the Biyskiy region are presented in Table 5.

Table 5. Quality parameters of double grains and average quality of oats grown in the Biyskiy region

Variety	Grain unit, g/l	Grain shape	Thousand grain weight, g	Kernel content, %	Hull content, %
Double grains	380	small, well formed	21.8	43.3	38.5
Oat quality across the Biyskiy region	460	medium size	33.3	62.5	26.5

When these grains are present in the feedstock, technological properties of the oat are considerably degraded (hull content by weight might reach 40%), kernel content is decreased, and besides, certain processing challenges also arise. Double grains images are presented in Fig. 2.

Moreover, double grains have very poor sowing and foraging properties, so batches with dual grains shall be rejected.

Oat hull content (mass fraction of double grains) varies greatly and depends on the oat variety, weather conditions, cultivation practices, soil conditions, and might also be hereditary.

Grains with two hulls have poor nutritional value (low kernel content, down to 45.5%), however, while they are removed from the grain mixture, a considerable part of large, well-formed grains are removed with them, as their geometric sizes are quite similar.

According to the standard requirements, in grain to groats processing, dual grains are classified as grain admixture.

In this paper, we present studies of grain to groats processing with oats containing dual grains. For the tests, we selected batches of Korifey variety collected in the piedmont zone of Altai Krai, with various mass fractions of double kernels.

Quality parameters of grains compliant with standard requirements, and grains supplied for processing to groats, are presented in Table 6.

Fig. 2. Left to right: double grains, kernel hull, kernel with one hull and coarse hulled kernel.

Table 6. Quality parameters of oat grains compliant with standard requirements and grains supplied for processing

Parameters	Quality parameters of grain supplied for processing		
	as per standard requirements	as per process specifications according to the applicable codes and standards	as per proposed technology
Moisture content, %	min. 13.5	13.0	13.5
Grain unit, g/l	min. 460	465	430
Kernel, %	min. 63.0	63.5	61.1
Weedy admixture, %	max. 3.0	2.0	3.6
Grain admixure, % including	max. 7.0	2.9	5.5
small grains, %	max. 5.0	2.0	2.2
Double grains, %	classified as grain admixture, not regulated separately	1.4	6.4
Hull content, %	not regulated	26.6	32.6

Studies have shown that mass fraction of double grains within the feedstock grain might reach up to 10 %.

Processing such oat batches in accordance with standard requirements is not cost effective, as both end product output and capacity are reduced.

Use of special equipment to remove external hulls from double grains increases volumes of crushed grain and content of normal grain in grain screenings. When grains are graded by size, double grains fall into the coarse category, which reduces not only capacity, but also efficiency of the whole oat processing facility. In accordance with standard requirements, large grains and double grains were hulled in the same hulling machine. At the same time, in double grains only one external hull is removed.

Study of double grain geometrical parameters showed that its length is comparable to sizes of larger grains, while hulled grains are similar in size to coarse oat hulled grains and to small grains.

When hulling is over, size similarity makes machine grading of this mixture even more complicated, which results in producing off-spec or low grade products [11].

Mass fraction of unhulled grains in the end product depending on the double grains content is presented in Table 7.

The provided data suggest that in technological applications as per standard requirements, with increased mass fraction of double grains in oat feedstock, amount of unhulled grains in the end product is increased, which results in producing off-spec products. Use of grains with high double grain content for groat production brings us to conclude that, in order to obtain high quality products, we should reduce the capacity of oat processing facility down to 25%, however, increased number of cycles of the process equipment leads to higher fractions of crushed kernels and middlings, to deterioration of consumer properties, and as a result, a reduced output of the end product.

In order to resolve this issue, we deiced to separate double grains into a segregated category at the stage of fractionation. We determined geometrical dimensions and performed a comparative analysis of different types of oat grains that contain double grains. The results of studying coarse (large) grains, double grains, and small grains of oat are presented in Fig. 3.

During the study, we have experimentally confirmed the utility of separating this fraction based on the length of grains.

Corresponding geometrical dimensions suggest that these oat grain fractions might be processed together, within the same processing schemes.

In order to improve the existing technology, we carried out comparative studies of processing oat with high double grain content as per standard requirements and as per the technology we proposed.

In order to eliminate the above challenges of hulling process and further grading of hulled products, we proposed to use drum separators to segregate double grains as a separate fraction and to feed it into the hulling system together with the small grains fraction.

Table 7. Mass fraction of unhulled grains in the end product depending on the double grains content

Parameter	Double grains mass fraction, %					Standard requirement
	2	4	6	8	10	
Mass fraction of non-hulled grain in the end product, %	0.7	1.2	2.0	2.4	2.9	max. 0.4

Fig. 3. Left to right: large oat grains, double grains, and small grains.

During hulling, separating the exterior hull in the grain with double coating allowed to make the second hulling and groat grading more efficient, due to corresponding geometrical dimensions of the obtained grains and small grains.

Thus, a modified grain fractionation regime and an introduction of a new fraction into grain processing allowed to use feedstock with double grains content for producing oat flour in conformity with standard requirements.

Designing a processing technology for oat grains with small grains mass fraction below 20%. Oats used in groat production must necessarily correspond to the standard requirements, in respect to such main traits as size, uniformity, limited presence of small grains.

In processing oat grains delivered to the plant we selected batches with high content of small grains. In unfavorable years, small grains fraction might reach up to 20%. Use for such grain in groat production is not cost efficient, as studies have shown that presence of small grain fractions affects both process and economic efficiency of the processing facility. As per standard requirements, such grain is used as forage, as otherwise considerable part of small grains would be removed as screenings during preparation for processing.

However, these grains tend to have a high kernel content and a low hull content. Quality parameters of small grains in comparison to average quality of oats grown in the Biyskiy region are presented in Table 8.

Provided data suggest that small oat grains might well be used for groat production.

In order to make grains to groat processing more efficient, for oat with high content of small grains, we modified the fraction segregation method [12].

As we studied fraction segregation, we used grains with the following quality parameters (Table 9).

Provided data suggest that quality parameters of the grain used for the study are considerably different from the standard ones. In order to determine technological properties of the grain within the experiment, we selected 9 mm oat grains.

As per the standard requirements, small grain classification and fraction segregation are based on grain thickness (riddling size 1.8 × 20). However, small fraction segregation based on grain thickness has one significant disadvantage for oat grain processing.

This oat processing procedure is efficient when working with standard grains.

For processing off-spec oat batches, we proposed a processing scheme based on oat grain segregation by grain length, using a drum separator with a 9 mm cell.

A change of fractionation criteria allowed to obtain coarse oats with weedy and grain admixtures of 0.06–0.1% max.

Grain remaining from the primary segregation, with weedy and grain admixtures, was sent to the grain purification stage [12].

Grain purification performance for the second fraction, as per standard technology and as per the proposed technology, is decribed in Table 10.

Table 8. Quality parameters of small grains and average quality of oats grown in the Biyskiy region

Variety	Grain unit, g/l	Grain shape	Thousand grain weight, g	Kernel content, %	Hull content, %
Small grains	540	small, well formed	24.8	67.6	22.5
Oat quality across the Biyskiy region	460	medium size	33.3	62.5	26.5

Table 9. Quality parameters of oat grains compliant with standard requirements and grains supplied for processing

Parameters	Quality parameters of grain supplied for processing		
	as per standard requirements	as per process specifications according to the applicable codes and standards	as per proposed technology
Moisture content, %	min. 13.5	13.3	14.1
Grain unit, g/dm^3	min. 460	465	480
Kernel, %	min. 63.0	61.1	60.6
Weedy admixture, %	max. 3.0	2.0	4.6
Grain admixture, % including small	max. 7.0	2.9	11.8
grains,	max. 5.0	3.5	4.1
Oat grains: kernel length max. 9 mm, %	not regulated	9.3	12.2

Table 10. Quality parameters of oat grain before hulling as per standard and proposed technologies

Oat grain admixtures	Weight ratio, %	
	as per process specifications according to the applicable codes and standards	as per proposed technology
Weedy admixture, including: - organic impurities - oatgrass - weed seeds	0.33 – 0.16 0.17	0.35 – 0.17 0.18
Grain admixture, including: - hulled grains - crushed grains - peas - barley - wheat	0.75 – – 0.48 0.27 –	0.60 – – 0.30 0.30 –
Valid grain content in screenings, max.	65.0	3.6
Weedy admixture content in the end product	0.35	0.30

Provided data suggest that if grain is prepared for hulling as per the recommended standard technology, the content of valid grain in grain screenings achieves up to 65%. Loss of this grain in relation to physical weight of the processed batch reduces the profit margin of the oat processing facility.

Use of an admixtures-small grains segregation principle based on length and thickness of grains allowed to achieve a high degree of purification, without loosing small grains into screenings. Small oat grains purification based on grain length was performed with a Pectus K233A sieve, with drum polymer cells d 5.2 mm, manufactured by TekhMashPolimer LLC (Perm). Further use of the rotating sieve surface of ZMB-3 bolter with elongated openings 2.6 × 20 mm and 2.8 × 20 mm (depending on the oat variety: needle-like or pear-shaped) allowed to separate the remaining admixture by thickness. Small fraction was sent for processing, while weedy and grain admixtures, diverted into the storage hopper. Content of weedy and grain admixtures in small fraction before and after grain processing according to the proposed technology are presented in Table 11.

Provided data suggest that fraction segregation method we proposed allowed to efficiently purify small oat grains and to use grains with high content of small grains for groat production.

Thus, processing oat grains with the proposed technology allows to process oat batches with mass fraction of small grains (below 9 mm) up to 20%, obtaining groat that corresponds to the standard requirements.

Designing a processing technology for oat grain mixtures. A grain mixture is a mixture of two or more types of grain, when at least one of them makes up to at least 15%. In our study, we used grain batches with oat content 70–85%, while wheat, barley, and pea amounts were below 30%.

Grain mixtures are perfect forage for poultry, both in industrial and household setting. They have a high crop capacity, convenient price, and have an ample scope of various applications. Jointly planted crops are beneficial for both forage and grain nutritional values. In oat grain, protein content is increased by 1.0–1.2%, the same is applicable to fats, etc. [13].

Oat grains in such batches tend to be large, with a well formed kernel. Quality parameters of oat separated from the grain mixture are described in Table 12.

Provided data suggest that in the context of grain shortage, it seems reasonable to use grain mixtures for groat production.

Table 11. Weedy and grain admixtures in small fraction before and after grain processing according to the proposed technology

Admixtures in small oat grains	Weight ratio, %	
	before purification	after purification, max.
Weedy admixture, including: - organic impurities - oatgrass - weed seeds	1.92 0.8 0.82 0.30	0.14 – 0.10 0.04
Grain admixture, including: - hulled grains - crushed grains - peas - barley - wheat	5.4 2.1 0.55 0.6 1.1 1.05	1.4 1.2 – – – 0.2

Table 12. Quality parameters of oat segregated from grain mixtures, Korifey vatiety, and average quality of oats grown in the Biyskiy region

Variety	Grain unit, g/l	Grain shape	Thousand grain weight, g	Kernel content, %	Hull content, %	Kernel volume, mm^3
Oat from grain mixtures	530	large	38.4	65.6	23.2	32.8
Korifey	550	large	38.0	65.0	24.0	33.0
Oat quality across the Biyskiy region	460	Medium size	33.3	62.5	26.5	29.1

Grain mass supplied to the processing facility contains various admixtures, apart from the oat itself [14]. Grain batches originally represent a mixture of grains of various cultural and weedy plants.

Such admixtures as barley, wheat, and pea represent obstacles for oat purification, which results in a complicated multi-step purification procedure and decreased cost effectiveness.

As per standards requirements, in order to segregate such amount of admixtures, the grading procedure is repeated, and special grain cleaning machines are used.

Oat grain cleaning, as per standard technology, allows to process grain with mass fraction of weedy and grain admixture below the limit values for 1st category grain.

Loss of normal grain is grain screenings.

Processing grain for groat production suggests further grading of batches based on the weedy content.

That is why, during grain acceptance at the facility, actual losses of feedstock are calculated, indicated admixtures are separated, and their respective volumes are introduced into the quality certificate of the batch. Based on the feedstock loss to screenings, a batch of grain mixture is formed, for further processing into groat. During the study of grain cleaning line operation, we used grain with the following quality parameters (Table 13).

We proposed a technological procedure for cleaning this grain [15]. It differs from the technology prescribed by standard documentation, as it suggests different grain and weed admixture segregation parameters, and consists of four consecutive stages.

Our technological procedure allowed to obtain products in conformity with the standard specifications from grain with up to 24% of admixtures.

Product costs for non-standard oat grains with the above non-conformities was calculated on the basis of the actual prices at that time, 3000 rubles/ton, and 2500 rubles/ton for oat grain mixtures. Standard output of Hercules oat flakes being 60.0% and 55.0% for grain mixtures. We used standard grain as control.

Product costs calculation for processing non-standard oat grains is presented in Table 14.

Thus, a complex approach to rehabilitation of Russian-made equipment allows to use non-standard oat grain for production of oat groat in conformity with the standard requirements, with product costs decrease down to 17.8 %.

Table 13. Quality parameters of oat grain mixtures

Parameters	Quality parameters of grain supplied for processing, %		
	as per standard requirements	as per process specifications according to the applicable codes and standards	as per proposed technology
Moisture content	max. 13.5	13.2	13.4
Kernel	min. 63	63.3	55.8
Admixture fraction:			
weedy	max. 3.0	2.5	3.2
grain	max. 7.0	4.4	19.6

Table 14. Product costs of processing non-standard oat grains

Grain non-conformity	Product costs, 1 ton, rubles	Decrease of product costs, %	Profit margin, %	Grain price per 1 ton, inclusive of VAT (rubles)	Groat price per 1 ton, inclusive of VAT (rubles)
Standard grain	6265		10	3000	7580
Moist, st.	6640	–	3.8	3000	7580
Moist, prop.	6305	5.3	9.3	3000	7580
With mass fraction of double grains up to 10% st.	7233	–	-4.7	3000	7580
With mass fraction of double grains up to 10% prop.	6544	10.5	5.3	3000	7580
With mass fraction of small grains up to 20% st.	7340	–	-6.1	3000	7580
With mass fraction of small grains up to 20% prop.	6718	9.2	2.3	3000	7580
Oat grain mixtures, st.	7428	–	-7.2	2500	7580
Oat grain mixtures, prop.	6305	17.8	9.3	2500	7580

Note. *st.– standard technology, *prop.– proposed technology.

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