



MODES OF PRODUCTION SMALL CORN FLAKES IN SEMI-INDUSTRIAL CONDITIONS

Abstract

The article presents study results of steaming and tempering modes effect on the yield and quality of small corn flakes. Production of small corn flakes was carried out in semi-production conditions on the basis of a test section of the existing machine-building operation OLIS LLC, which allowed to get as close as possible to the production conditions. The study consisted of 2 series of experiments: in the first series of experiments, five identical samples of corn grit with an initial moisture content of 13.1% were sent to the steaming stage, where it was subjected to water-heat treatment for a specified period of time (2.5; 5; 7.5, 10 and 12.5 minutes), with increasing steaming time, the tempering time gradually increased by 10 minutes, from 10 to 50 minutes, respectively. In the second series of experiments, the grit was moistened by cold conditioning to a predetermined moisture content of $16 \pm 0.25\%$, moistened for 12 hours, and then moistened grit was subjected to water-heat treatment at the same parameters as in the first series. The initial sample of corn grit No. 4 was obtained in the factory and had the following quality indicators: moisture content – 13.1%; ash content – 0.58%; the starch content – 71.1%.

The technological scheme of small corn flakes production in semi-production conditions included the following steps: grit moistening by a special device that sprays water for 15-20 seconds, and wetting in special sealed containers of grit samples (if necessary); grit steaming in the steamer camera of periodic action of EPP-1; tempering for 10-50 minutes in thermostable conditions; flattening of the obtained product on a rolling mill "EVV-1" with smooth rollers at a gap of 0.3-0.4 mm; drying the flattened product on a laboratory dryer; control on the laboratory dispenser RLU-1 (sieving on a sieve No. 067) for extraction of flour products.

It was found that as a result of grit steaming with initial moisture content (13.1%) and subsequent flattening in semi-production conditions a lot of meal was formed – 33.6 and 23.3% with the duration of steaming for 2.5 and 12.5 minutes, respectively, with an ash content of 0.64-0.57% and a starch content of 63.2-63.4%. With the ash content of the original grit of 0.63% and the starch content of 71.1%, it indicated that although moisture penetrated into the inner layers of the grit during conditioning, yet it was not enough on the surface. Therefore, high-ash peripheral grit particles were worse exposed to flattening, crushed and formed meal. Thus, the selected modes of small corn flakes production in semi-production conditions were not sufficient to provide the grit particle with the necessary structural and mechanical changes, and further increase in the duration of processing was impractical, as it significantly increased energy consumption and reduced flakes production productivity.

Preliminary wetting of grit to a moisture content of $16 \pm 0.25\%$ and subsequent steaming at the same parameters as grit flakes with a starting moisture content of 13.1% showed a significant decrease of flour products output, which amounted to 13.7-7.8% at 2.5 and 12.5 min of steaming, respectively. However, the additional grit moistening before steaming led to an increase in flakes moisture content, which requires higher energy consumption during their drying and bringing them to standards (less than 13.0%), guaranteeing their storage for 6-9 months.

The technologically appropriate wet-heat processing mode of corn grit in the production process of flakes in semi-production conditions, to obtain small corn flakes according to the scheme of preliminary wetting of grit, steaming it in a steamer of periodic action, short-term tempering, flattening, drying and control of flakes on meal separation, is a grit moisture content before steaming at $16 \pm 2.5\%$, steaming at atmospheric conditions for 7.5-10 min, duration of tempering – 30-40 min. The obtained flakes do not require cooking, but can be brewed in boiling water for 4-5 minutes.

Key words: corn, tempering, steaming, modes, flakes, organoleptic evaluation.

Introduction

Flaking grits are the most valued product of the dry milling process. Flaking grit yield is important to dry millers, but is challenging as a breeding target [1]. Its depend on kernel hardness [2-4], test weight [3, 6, 8], kernel density [10], and protein content [12].

Processes of grit steaming and flattening are important processes in the production of flakes. The main function of steaming is to reduce breakage and produce stronger flakes [5]. Adding heat and moisture softens the grit, making it more plastic and less prone to brittle fracture. The strengthening of the flakes occurs when the adhesion between the structural elements of the flakes increases. Also, during hardening and peeling of steam, the starch is leached from the granules and forms an adhesive phase which holds the starch granules together and secures the torn layer of shells on the flake surface [7].

During flattening, the grit passes between two

rolls, which usually have a diameter of 400-500 mm. Using rollers of larger diameter on flattening machines compared to roller machines with roller diameters of 250 or 300 mm allows to establish a smaller gap between the rolls by a special mechanism, which leads to an increase in compression deformation [9], and permits to obtain smaller thickness of flakes. Due to the strong elastic deformation, the thickness of the obtained flakes is always larger (0.5-0.6 mm) compared to the roll gap (0.3-0.4 mm), in addition, as the particle size increases, the edges of the flake particles become broken, and the larger the particle size and less working gap – the bigger effect of broken edges (smaller or cut grits will expand less and therefore have fewer broken edges), which is of particular importance for laboratory equipment with smaller roller diameters [5].

With regard to wet-heat processing modes, in the production of large corn flakes, corn grits are treated in a steam cooker at a temperature above 100 °C for a time.



This treatment softens the hard grits. During boiling additional water is introduced in the form of condensing steam, and the moisture content after treatment increases to 30-35%. Afterwards, hot grits are dried in hot air dryers, ground with rollers, which flatly compress grits. Then flakes are rolled up in huge cylindrical furnaces with air temperature 600 °C and the flakes are tossed around the rotating cylinder. The cylinder is angled so that the flakes swirl around and pass through it quickly enough, which prevents them from consuming too long at high temperature [7].

Tempering conditions had significant effects on the specific weight, thickness and water absorption of the flakes as well as on the amount of fine material (<2 mm) produced during flaking. Flake strength correlated significantly with grit strength and flake thickness [11]. Any heat treatment including corn flaking procedure led to change in chemical composition of grits: to reduce resistant starch content to almost half its original level (from an average of 6.7% in raw grits to 2.9% in cooked grits to 3.2% in toasted flakes) [13], to the appearance of partial gelatinization of starches which is clearly confirmed by an increase in the average volume diameter in cold water, a decrease in the gelatinization enthalpy, and a loss of birefringence in polarized light [15], to reduce aflatoxin B1 contamination level [14], to inhibit grain spoilage microorganisms [16].

Materials and methods

The corn grit №4 was the subject of research, produced in the operation conditions and had the following quality indicators: moisture content – 13.1%; ash content – 0.58%; starch content – 71.1%.

The object of the study was to establish the optimum water-thermal regimes that would provide the highest yield and the best quality of flattened products.

Production of small corn flakes was carried out in semi-production conditions on the basis of a test section of the existing machine-building operation OLIS Llc, which allowed to get as close as possible to the production conditions. The study consisted of two series of experiments:

– in the first series of experiments (Fig. 1A), five identical samples of corn grit with an initial moisture content of 13.1% were sent to the steaming stage, where it was subjected to water-heat treatment for a specified period of time: 2.5; 5; 7.5, 10 and 12.5 minutes. With increasing steaming time, the tempering time gradually increased by 10 minutes, from 10 to 50 minutes, respectively.

– in the second series of experiments (Fig. 1B), the grit was moistened by cold conditioning to a predetermined moisture content of 16%. Then grit after 12 hours moistening was directed to steamer camera, where was subjected to water-heat treatment at the same parameters as in the first series.

The technological scheme of small corn flakes production in semi-production conditions (Pic. 1) included the following steps:

– grit moistening by a special device that sprays water for 15-20 seconds, and wetting in special sealed containers of grit samples (if necessary);

– grit steaming in the steamer camera of periodic action of EPP-1;

– tempering for 10-50 minutes in thermostable conditions;

– flattening of the obtained product on a rolling mill "EVP-1" with smooth rollers at a gap of 0.3-0.4 mm;

– drying the flattened product on a laboratory dryer;

– control sieving on the laboratory sifter RLU-1 (sieving on a sieve No. 067) for extraction of meal products.

The heat treatment of grit was carried out as follows: the product with initial moisture or pre-moistened was directed into the steamer camera, subjected to steam treatment for a certain period of time, with periodic stirring of the product. The feature of this method of steaming is that due to the peculiarities of the steamer structure, excessive steam pressure is not created in its chamber and grit are treated with ordinary atmospheric pressure steam.

Products obtained under different modes were evaluated by: organoleptic evaluation (visual appearance and shape); quantitative evaluation (yield of flakes, size, %); quality evaluation (moisture content, ash content, starch); consumer evaluation (trial and brew rate).

The amount of water (K) required for moistening was determined by the formula:

$$B = "G" \cdot (100-A) / ((100-B) - 1), \quad (1)$$

where B is the amount of water added when moistened, g;

G – mass of moistened grit, g;

A – initial moisture content of the grit, %;

B – final moisture content of the grit, %.

The output of the flakes was determined by the amount of overtails of the sieve No. 067 during sifting 100 g of the flattened product; size of flakes – in size modules when sifting on a set of sieves with Ø 2,8; 2,6; 2,3; 2,0; 1,6 mm.

To study the physicochemical parameters of corn products (moisture content, ash content, starch content), standard methods were used: moisture was determined by drying in a drying oven at a temperature of 130° C in accordance with GOST 13586.5-93, ash content – ashing in a muffle furnace at a temperature of 800° C in accordance with DSTU ISO 2171: 2009, starch content – polarimetric method by the Evers according to GOST 10845-98.

Results and discussion

As a result of the 2-series study of the modes of wet-heat processing (WHP) in semi-production conditions, we determined the significance of such technological operations as: pre-moistening of grit and duration of steaming for output (Fig. 2) and quality of the products of flattening (Fig. 3-4) and the obtained flakes (Fig. 5, Table 1).

The first series of experiments without pre-moistening showed that as a result of grit steaming with initial moisture content (13.1%) and subsequent flattening in semi-production conditions a lot of meal was

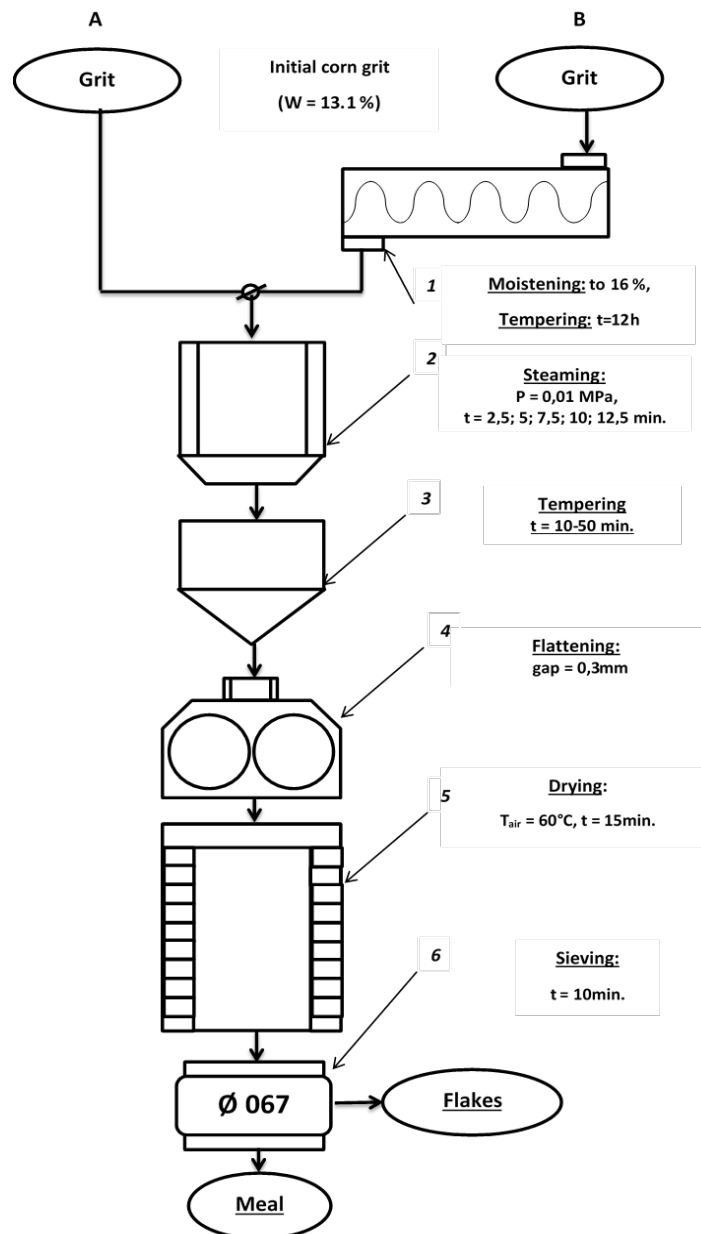


Fig. 1 – Flow chart of production of small corn flakes in semi-production conditions

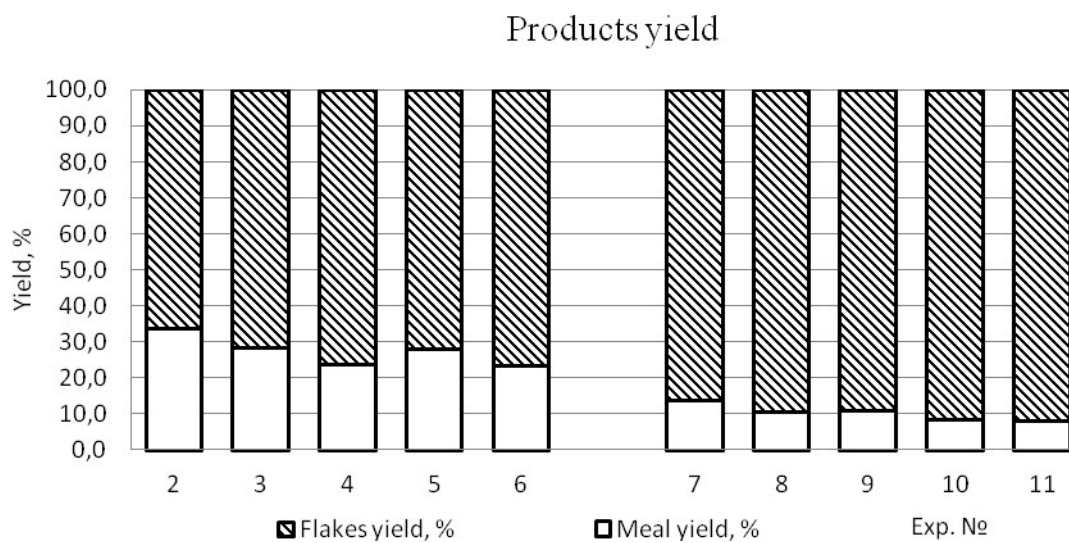


Fig. 2 – Product yield under different WHP modes

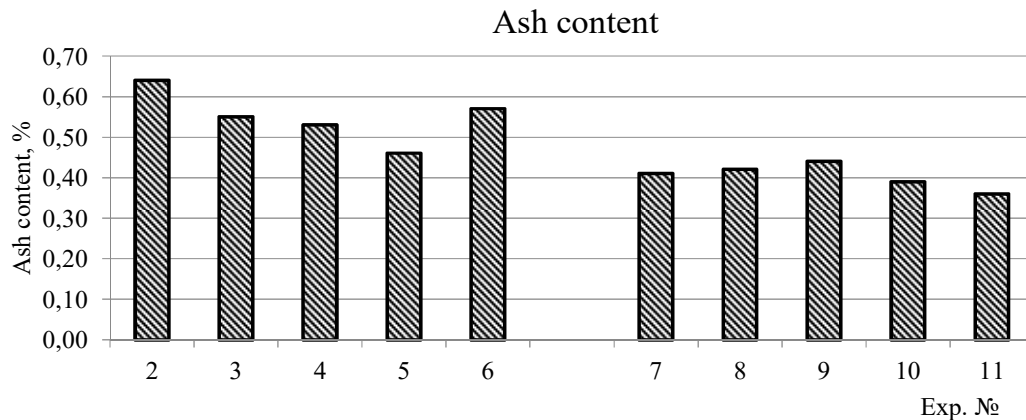


Fig. 3 – Ash content of products under different WHP modes

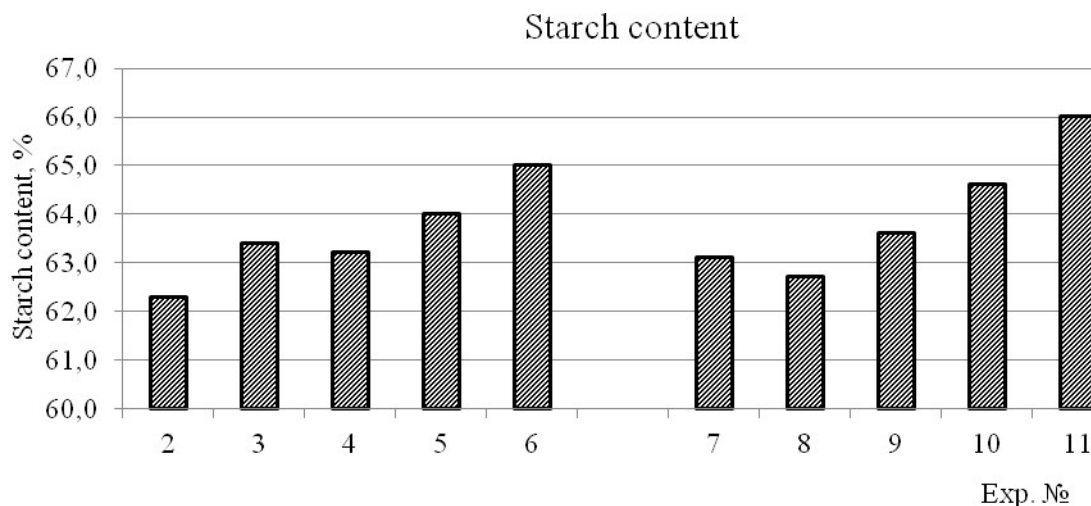


Fig. 4 – Starch content of products under different WHP modes

formed – 33.6 and 23.3% with the duration of steaming for 2.5 and 12.5 minutes, respectively, with an ash content of 0.64-0.57% and a starch content of 63.2-63.4%. With the ash content of the original grit of 0.63% and the starch content of 71.1%, it indicated that although moisture penetrated into the inner layers of the grit during conditioning, yet it was not enough on the surface. Therefore, high-ash peripheral grit particles were worse exposed to flattening, crushed and formed meal.

Thus, the selected modes of small corn flakes production in semi-production conditions were not sufficient to provide the grit particle with the necessary structural and mechanical changes, and further increase in the duration of processing was impractical, as it significantly increased energy consumption and reduced flakes production productivity.

With grit pre-moistening, steaming for 2.5 min and tempering for 10 min. (experiment 7) were not sufficient to provide the necessary elastic-plastic properties to the grit particle. In such modes, the yield of meal was 13.7%, and its ash content (0.41%) and starch content (63.1%), indicating that the ratio of the central part (endosperm) to the peripheral parts in its composition ex-

ceeded this same ratio in the original grit.

Increasing steaming time to 5 and 7.5 min and tempering time to 20 and 30 min (experiments 8 and 9), the yield of meal decreased to 10.2% and 10.6%, respectively, with the ash content of the obtained flakes increasing by 0.01-0.02%, which is explained by the migration of ash substances from the inner parts to the periphery [17], the content of starch increased, which, in turn, was due to a decrease in the transition of endosperm particles to the meal.

Further increase in the duration of steaming to the levels of 10 and 12.5 min, allowed to reduce the yield of meal to values of 8.3% and 7.8%, respectively. Considering the effectiveness of the WHP from the quantitative side, these two modes were the best (experiments 10, 11).

Thus, preliminary wetting of grit to a moisture content of $16 \pm 0.25\%$ and subsequent steaming at the same parameters as grit flakes with a starting moisture content of 13.1% showed a significant decrease of meal products output, which amounted to 13.7-7.8% at 2.5 and 12.5 min of steaming, respectively. However, the additional grit moistening before steaming led to an increase in flakes moisture content, which requires higher energy



consumption during their drying and bringing them to standards (less than 13.0%), guaranteeing their storage for 6-9 months.

Further the quality of the WHP was evaluated by the size module. In this indicator, own flakes became the control sample (experiment 1), which are currently being produced at Skvyrsky CCP. Having previously screened the flakes of "Skvyryanka" and obtained the value of this indicator, we proceeded to the estimation of the size modules in the obtained flattened products. The largest flakes size and their best size alignment were obtained under more stringent conditions (Tab. 1).

Organoleptic evaluation is a key parameter determining optimal WHP modes, as the buyer first evaluates the product visually when choosing a product: for some aesthetic component, the product should be "pleasing" to the consumer's eye. Thus, in the organoleptic evaluation of flakes, it is important that the corn flakes are strong, of the same size and consistency, not crumble. Since they are much smaller than oats, such an indicator as the thickness of flakes is not so important to them. Fig. 5 shows the appearance of the products obtained under different WHP modes.

Based on the above facts and organoleptic evaluation, technologically appropriate wet-heat processing modes of grit to obtain small corn flakes are moisture content before steaming at $16 \pm 2.5\%$, steaming at atmospheric conditions for 7.5–10 min, duration of tempering

–30–40 min. Steaming of grit at such modes allows to get the output of flakes at the level of 91.6–92.2%. According to preliminary organoleptic evaluation, the flattened product obtained under such modes is characterized as flakes (Fig. 5C) and is similar in appearance to the control sample (Fig. 5A).

Absence of pre-moistening step up to 16% (Fig. 5E, 5F), or reduction of steaming time below 10 min. (Fig. 5C), does not allow to change the physical, chemical and technological properties of grit in full, as indicated by the considerable amount of meal formed during flattening. The large amount of meal at the stage of flattening indicates insufficiently plastic properties of grit.

Further increase in the steaming time above 10 minutes, in turn, allows to increase the yield of the flatten kernel and to reduce meal output, but the excessive presence of grit in the steamer chamber leads to further smearing of the grit, clogging of technological equipment, high moisture content of flakes, therefore, the flakes obtained in this mode are characterized by partial adhesion and nonuniform size (Fig. 5D).

Evaluating the consumer properties of flakes it is found that the obtained flakes do not need cooking, but can be brewed in boiling water for 5-7 minutes in softer modes. With the change of modes to the greater side, the duration of brewing decreased slightly: at certain optimal WHP modes, the preparation time of small corn flakes in this way is 4-5 minutes.

Table 1 – Granulometric composition (fraction yield, %) and organoleptic evaluation of flakes

Fraction	Control	Series №1. Without grit pre-moistening					Series №2. With grit pre-moistening				
		2,5	5	7,5	10	12,5	2,5	5	7,5	10	12,5
Steaming time, min.											
№ of study	1	2	3	4	5	6	7	8	9	10	11
Ø--/2,8	19,37	1,80	1,62	2,21	2,48	3,76	4,62	4,99	8,29	11,94	18,46
Ø2,8/2,6	22,94	7,89	2,39	4,79	9,38	6,23	10,87	10,16	13,61	18,30	18,01
Ø2,6/2,3	24,63	14,79	9,66	13,34	16,08	14,81	22,54	19,78	24,93	24,41	23,84
Ø2,3/2,0	11,39	17,78	22,69	23,06	19,44	25,85	32,14	28,69	29,26	21,56	19,29
Ø2,0/1,6	15,72	27,14	41,39	28,81	24,38	26,10	19,65	22,65	15,59	13,15	12,60
Ø1,6/--	5,95	30,59	22,23	27,78	28,25	23,25	10,18	13,70	8,32	10,64	7,80
Total	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
Size module, mm	2,36	1,74	1,76	1,76	1,80	1,85	2,11	2,04	2,19	2,22	2,31
Appearance	Flakes (control)	Flatten kernel	Flatten kernel	Similar on flakes	Similar on flakes	Flakes, the best result in the 1st series	Flakes	Flakes	Flakes (best result)	Flakes (best result)	Product sticking registered



Fig. 5 – The appearance of flakes in different modes:

a – Control; b – steaming time 10 min. (with pre-moistening); c – steaming time 2.5 min. (with pre-moistening); d – steaming time 12.5 min. (with pre-moistening); e – steaming time 2.5 min. (without pre-moistening); f – steaming time 12.5 min. (without pre-moistening).

Conclusions

The technologically appropriate wet-heat processing mode of corn grit in the production process of flakes in semi-production conditions, to obtain small corn flakes according to the scheme of preliminary wetting of grit, steaming it in a steamer of periodic action, short-term tempering, flattening, drying and control of flakes on meal separation, is a grit moisture content before steaming at $16 \pm 2.5\%$, steaming at atmospheric conditions for 7.5-10 min, duration of tempering – 30-40

min. The obtained flakes do not require cooking, but can be brewed in boiling water for 4-5 minutes.

Using the stage of original grit moistening in the scheme of small flakes production allows to reduce the duration of heat treatment, i.e. preserve valuable nutrients and to decrease the production cost of flakes. This stage is not applied in production conditions, so the attempt to introduce and reproduce in the technological process of these modes and conditions of flakes production is a perspective direction for further research.

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РЕЖИМИ ВИРОБНИЦТВА ДРІБНИХ КУКУРУДЗЯНИХ ПЛАСТІВЦІВ У НАПІВВИРОБНИЧИХ УМОВАХ

Анотація

У статті наведено результати дослідження впливу режимів пропарювання та темперування на вихід та якість дрібних кукурудзяних пластівців. Вироблення дрібних кукурудзяних пластівців здійснювали у напів-виробничих умовах на базі випробувальної ділянки діючого машинобудівельного заводу ТОВ ОЛІС, що дало змогу максимально наблизитись до виробничих умов. Дослідження склалися з 2-х серій дослідів: у першій серії дослідів п'ять ідентичних зразків кукурудзяної крупи з початковою вологістю 13,1 % направляли на етап пропарювання, де вона піддавалась водно-тепловій обробці протягом заданих проміжків часу (2,5; 5; 7,5; 10 та 12,5 хв.), при цьому із збільшенням часу пропарювання, збільшувався і час темперування крупи поступово на 10 хв, від 10 до 50 хв., відповідно. У другій серії дослідів крупу зволожили шляхом холодного кондиціонування до заданого значення вологості $16 \pm 0,25$ %, відволожували протягом 12 годин, а потім зволожену крупу піддавали водно-тепловій обробці при тих же параметрах, що і в першій серії. Вихідний зразок кукурудзяної крупи №4 був отриманий у заводських умовах та характеризувався наступними показниками якості: вологість – 13,1 %; зольність – 0,58 %; вмісту крохмалю – 71,1 %.

Технологічна схема виробництва дрібних кукурудзяних пластівців у напіввиробничих умовах включала наступні етапи: зволоження крупи за допомогою спеціального пристрою, що розприскує воду протягом 15-20 с, та відволоження у спеціальних герметичних ємностях зразків крупи (при необхідності); пропарювання крупи у камері пропарювача періодичної дії ЕПП-1; темперування протягом 10-50 хв. у термостабільних умовах; плющення отриманого продукту на вальцьовому верстаті «ЕВВ-1» з гладкими вальцями при зазорі 0,3-0,4 мм; сушіння плющеного продукту на лабораторній сушарці; контроль на лабораторному розсійнику РЛУ-1 (просіювання на ситі №067) для вилучення мучнистих продуктів.

Встановлено, що в результаті пропарювання крупи з початковою вологістю (13,1 %) та подальшого її плющення у напів-виробничих умовах утворювалось багато мучки – 33,6 та 23,3 % при тривалості пропарювання 2,5 та 12,5 хв. відповідно, із зольністю 0,64-0,57 % та вмістом крохмалю 63,2-63,4 %. При зольності вихідної крупи 0,63 % та вмісту крохмалю 71,1 %, це свідчило про те, що волога при кондиціонуванні хоча проникла у внутрішні шари крупинок, але на поверхні її було недостатньо. Тому високозольні периферичні частинки крупинок гірше піддавались плющенню, подрібнювались та утворювали мучку. Таким чином, обрані режими виробництва дрібних кукурудзяних пластівців у напіввиробничих умовах були недостатніми для того, щоб надати крупинці необхідних структурно-механічних змін, а подальше збільшення тривалості обробки було недоцільним, так як істотно підвищувало енерговитрати та знижувалось продуктивність процесу виробництва пластівців.

При попередньому зволоженні крупи до вологості $16 \pm 0,25$ % та наступного пропарювання при тих же



параметрах, що і при отриманні пластівців з крупи з вихідною вологістю 13,1 %, спостерігалось суттєве зменшення виходу мучнистих продуктів, яке склало 13,7-7,8 % при 2,5 та 12,5 хв пропарювання, відповідно. Однак, додаткове зволоження крупи до пропарювання призводило до підвищення вологості пластівців, що потребує збільшення енерговитрат при їх сушінні та доведенні до норм (не більше 13,0 %), гарантуючих їх зберігання протягом 6-9 міс.

При виробництві пластівців у напіввиробничих умовах технологічно доцільним режимом ВТО крупи з кукурудзи при отриманні дрібних кукурудзяних пластівців за схемою попереднього зволоження крупи, пропарювання її у пропарювачу періодичної дії, короткочасного темперування, плющення, сушіння та контролю пластівців з метою вилучення мучки, є вологість крупи перед пропарюванням $-16 \pm 2,5$ %, пропарювання при атмосферних умовах протягом 7,5-10 хв., тривалість темперування – 30-40 хв. Отримані пластівці не потребують варіння, а можуть бути запарені у окропі протягом 4-5 хв.

Ключові слова: кукурудза, волого-теплова обробка, пропарювання, режими, дрібні пластівці, органолептична оцінка.

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