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INFLUENCE OF GRAIN PROPERTIES AND PARAMETERS OF MICROWAVE TREATMENT ON THE EFFICIENCY OF SORGHUM GRAIN POPPING

Abstract

The study focuses on establishing the regularities of the influence of sorghum grain properties and microwave (MW) treatment parameters on the efficiency of the popping process. The relevance of the work is due to the need to substantiate the technological conditions for producing popped sorghum grain and to take into account varietal and size-related characteristics of the raw material when selecting microwave treatment modes. The aim of the study was to establish the influence of varietal, physical and fractional characteristics of sorghum grain, its initial moisture content and microwave treatment power on popping efficiency, and to substantiate rational process parameters for different grain fractions. The study was carried out using sorghum grain of the Dniprovsky, Kafrske and Fulgus varieties, whose initial moisture content was varied within 13–17 %, and microwave treatment power within 450–700 W at an electromagnetic field frequency of 2450 MHz and a treatment duration of 150 s. Process efficiency was evaluated by popping yield, bulk density and expansion ratio. It was established that, for all the studied varieties, the highest popping yield was achieved at 15 % moisture content and 700 W power. Under these conditions, popping yield for the Fulgus variety was 92 %, for Dniprovsky – 64 %, and for Kafrske – 52 %, which confirms the significant influence of varietal grain properties on the realization of popping ability. The Fulgus variety was characterized by the highest expansion ratio of popped grain – 11.0 – and the lowest bulk density of the finished product – about 69 kg/m³, indicating the formation of the most developed porous structure. A significant influence of kernel size on MW-popping efficiency was also established. For the fine fraction, the most effective modes were 14–15 % moisture content and 600 W power, at which the maximum popping yield was 76 %. Increasing the power to 700 W for this fraction was accompanied by signs of local overheating. For the coarse fraction, the highest popping yield – 92 % – was obtained at 15 % moisture content and 700 W power without signs of overheating. The established differentiation of rational modes depending on kernel size indicates that fractionation is not merely a mechanical grading operation of the raw material, but a technological technique that ensures the intensity of microwave heating is matched to the size characteristics of the kernels and prevents overheating of the fine fraction while simultaneously ensuring a high popping yield from the coarse fraction. The results obtained substantiate the feasibility of preliminary size separation of sorghum grain before MW-popping and of a differentiated selection of treatment modes for individual fractions, which creates the preconditions for improving the stability and technological efficiency of popped sorghum grain production.

Key words: grain, sorghum, Sorghum bicolor (L.) Moench; popped sorghum; puffed products; microwave treatment; popping; MW-popping; technological parameters; grain fractionation; popping yield.

Introduction

Expanding the range of ready-to-eat cereal products is a popular direction in the development of the food industry. Popped grain is of particular interest, as its porous structure, attractive organoleptic properties and ready-to-eat convenience make it suitable for use in the production of snacks, breakfast cereals, cereal mixes and bars [1, 2].

A promising raw material for obtaining such products is sorghum (Sorghum bicolor (L.) Moench), which is characterized by high adaptability to arid conditions and elevated temperatures. Sorghum grain is gluten-free and is a source of starch, protein, dietary fiber and biologically active compounds, which drives the expansion of its food-use applications [3, 4, 5]. The search for effective sorghum processing methods is particularly relevant for creating cereal products with high nutritional and consumer value.

One of the sorghum grain processing methods that has attracted interest is popping – a short-term, high-temperature treatment during which the internal moisture of the kernel generates water vapor pressure that causes expansion of the endosperm and the formation of a porous product structure [1, 6]. The use of microwave (MW) heating creates additional opportunities for intensifying this process due to the direct absorption of electromagnetic energy by the material and the high heating rate [7, 8].

Popping efficiency depends on the interaction between grain properties and processing regime parameters. Among the determining factors, researchers identify varietal and physical characteristics of the kernel, endosperm properties, initial moisture content and heating intensity [9-12]. For sorghum grain, considerable variability in popping ability has been established depending on the variety and treatment conditions; however, the combined influence of grain properties, fractional composition, moisture content and microwave treatment power requires further investigation [9, 10, 13].

In this regard, it is relevant to establish the regularities of the influence of sorghum grain properties and microwave treatment parameters on popping efficiency and to substantiate rational conditions for obtaining popped grain.

Literature review

Popping is based on the rapid heating of grain, during which the water inside the kernel turns into vapor and creates elevated internal pressure. Once a critical level is reached, the hull ruptures and the endosperm expands [1, 6]. Studies of the popping mechanism of corn have shown that the essential conditions for the process are a sufficient amount of internal moisture and the ability of the hull to withstand pressure until it ruptures [6]. At the same time, endosperm characteristics determine the degree of its expansion and the structure of the popped grain [14].

Unlike traditional heating methods, microwave energy is absorbed directly throughout the volume of the material, which ensures a high rate of heat energy delivery and a shorter process duration [7,8]. The efficiency of microwave heating is determined by the dielectric properties of the material, its moisture content and the conditions of exposure to the electromagnetic field [7,8]. Therefore, during microwave popping it is important to match the properties of the raw material with the intensity of energy input.

For sorghum, a significant dependence of popping ability on varietal characteristics has been established. Rooney and Rooney [9] showed that popping yield and expansion ratio significantly depend on genotype and growing conditions. Golubinova et al. [10] also found a considerable range of popping ability among different sorghum genotypes and established a relationship between popping indicators and the physical characteristics of the grain. Thus, the choice of a specific variety or genotype is an important factor when substantiating the modes for obtaining popped sorghum.

The direct influence of varietal physicochemical properties on microwave popping was studied by Mishra et al. [11]. The authors established significant differences between varieties in the yield and characteristics of popped grain and showed the dependence of process efficiency on bulk and true density, grain hardness, amylose content and pericarp thickness. This confirms the need to take into account the physical properties of the raw material when selecting microwave treatment parameters.

An important factor is the initial moisture content of the grain, since it is the internal water that serves as the source of steam that generates pressure and drives further expansion of the kernel [6, 12]. Mishra et al. [12] established the existence of an optimal moisture range for conditioning sorghum grain before microwave popping. At insufficient moisture content, the necessary internal pressure is not achieved, whereas excess moisture may reduce expansion efficiency and impair the characteristics of the popped grain. Similar patterns regarding the need to optimize moisture content and heating parameters were established in the studies of Nakade et al. [15] and Pawar et al. [16].

Another determining parameter is microwave treatment power, which directly affects the grain heating rate. As the intensity of energy input increases, the time required to reach the temperature necessary for steam formation and kernel expansion decreases. At the same time, excessive heating intensity can cause process non-uniformity and local overheating [7, 8, 12, 16]. Therefore, the efficiency of MW-popping is determined not by maximizing power as such, but by its match with the grain's properties and moisture content.

The results of previous studies also indicate the promise of MW-popping for sorghum. Mishra et al. [12], using mathematical design methods, determined the relationship between pre-conditioning and microwave treatment parameters. Study [17] established the dependence of popped sorghum characteristics on microwave treatment conditions, chemical composition and grain microstructure. The results obtained confirm the need for a comprehensive consideration of grain properties and process regime parameters.

Thus, the literature data indicate that the efficiency of sorghum popping is determined by the combined action of genotypic and physical grain properties, its initial moisture content and microwave heating intensity [9–12, 15–17]. At the same time, data on the simultaneous influence of grain fractional characteristics, moisture content and microwave treatment power on popping efficiency indicators under uniform experimental conditions remain insufficiently systematized. This substantiates the need for a comprehensive study of these factors and for establishing the regularities of their influence on the popping efficiency of sorghum grain.

The aim of the work was to establish the regularities of the influence of sorghum grain properties and microwave treatment parameters on popping process efficiency and to determine rational modes for obtaining popped grain. To achieve this aim, the influence of initial grain moisture content and microwave treatment power on popping yield was studied, the influence of varietal characteristics on yield, bulk density and expansion ratio of the product was determined, the regularities of the influence of grain fractional composition on MW-popping efficiency were established, and rational treatment parameters for fine and coarse sorghum grain fractions were substantiated.

Materials and methods

The object of the study was sorghum grain Sorghum bicolor (L.) Moench, grown under the conditions of Ukraine. To evaluate the influence of microwave treatment regime parameters, grain of the Dniprovsky, Kafrske and Fulgus varieties was used, which differed in morphological characteristics and kernel color. Further studies of the influence of grain fractional composition were carried out using grain of the Fulgus variety, which was selected as the model object for an in-depth study of the regularities of the MW-popping process. The physical characteristics of the sorghum grain of the studied varieties are presented in Table 1.

According to organoleptic quality indicators, the studied sorghum grain samples complied with the requirements of DSTU 4962:2008 "Sorghum. Specifications" and were characterized by the color and odor typical of healthy grain, without foreign impurities.

Before the experiments, the grain was conditioned to the required moisture content. Grain moisture content was adjusted by adding a calculated amount of water, followed by tempering under sealed conditions for 24 h at a temperature of (20±2) °C to ensure uniform moisture distribution throughout the kernel volume. The initial moisture content of the grain before microwave treatment was varied within 13, 15, 17 % when establishing varietal characteristics, and within 13-16 % when studying the

Table 1 – Physical characteristics of the sorghum grain of the studied varieties

Variety	Color	Thousand grain weight, g	Bulk density, kg/m^3	Moisture, % wb
Dniprovsky	light brown with dark spots	28.1b±0.1	820.3b ±2.0	12.5a±0.1
Kafrske	white	22.2a±0.2	700.4a ±2.4	12.3a±0.1
Fulgus	bicolor from light brown to dark brown	31.9c±0.2	869.8c ±2.0	13.0b±0.1

Mean ± Standard Deviation (S.D.); Different superscript letters within a column indicate statistically significant differences between means (P < 0.05); means sharing the same letter are not significantly different.

popping ability of grain separated into fractions.

MW-popping was carried out in a domestic microwave oven with an electromagnetic field frequency of 2450 MHz. microwave treatment power was varied within 450-700 W depending on the experimental design. During the study of the influence of grain moisture content and microwave treatment power, the process duration was 150 s.

To evaluate the influence of fractional composition, the grain was additionally separated into fine and coarse fractions by sieving through a sieve with a 4 mm hole diameter. The fine fraction included kernels passing through the Ø4 mm sieve; the coarse fraction included kernels remaining on the Ø4 mm sieve.

The efficiency of the MW-popping process was evaluated by popping yield (PY), bulk density of popped grain (BD) and expansion ratio (VER) [11].

Popping yield (PY, %) was determined as the ratio of the number of popped kernels to the total number of kernels in the tested sample (popped and unpopped) and was calculated using the formula:

$$PY = \frac{n_1}{n_1 + n_2} \cdot 100\% \quad (1)$$

where n_1 – amount of popped grains, pcs

n_2 – amount of unpopped grains, pcs

The bulk density of popped sorghum (BD, kg/m³) was determined as the ratio of the product mass to the volume of a measuring cylinder filled with the tested sample and was calculated using the formula [11]:

$$BD = \frac{m}{V} \quad (2)$$

where m – weight of popped grains, kg

V – volume of popped grains, m^3.

The volume expansion ratio (VER) was determined by the sand displacement method according to the procedure of Joshi et al. [11] and was calculated using the formula:

$$VER = \frac{V_1}{V_2} \quad (3)$$

where V_1 – final volume of popped sorghum grains, ml

V_2 – initial volume of pretreated sorghum grains, ml.

All studies were carried out in at least three replications. The results are presented as the mean value and standard deviation (Mean ± S.D.).

Results and discussion.

Influence of grain moisture content and microwave treatment power on the quality indicators of popped sorghum

One of the main factors that determine the efficiency of the MW-popping process for sorghum grain is its initial moisture content and electromagnetic treatment power. These parameters create the conditions for intensive heating of the kernel, evaporation of internal moisture and accumulation of the water vapor pressure required for its rupture [11,12].

To establish the regularities of the influence of microwave treatment regime parameters, the study was carried out on grain of the Fulgus, Kafrske and Dniprovsky varieties. The initial moisture content of the grain was varied within 13-17 %, and microwave treatment power was 450, 600 and 700 W at a constant process duration of 150 s. The results of the study on the influence of grain moisture content and microwave treatment power on the popping yield of sorghum are presented in Fig. 1.

Analysis of the results obtained showed that the pattern of influence of grain moisture content on popping yield was similar for all the studied varieties. At a microwave treatment power of 450 W, the lowest popping yield values were observed regardless of varietal characteristics and initial moisture content of the raw material. Increasing the power to 600 W was accompanied by an increase in popping yield, while the maximum values of the indicator were achieved at a power of 700 W.

For all the studied varieties, the highest popping yield was observed at 15 % moisture content. Reducing the moisture content to 13 % led to a deterioration in the realization of the grain's popping ability due to insufficient water vapor formation and less intensive accumulation of internal pressure inside the kernel. Increasing the moisture content to 17 % was also accompanied by a decrease in popping yield, which can be explained by the increased share of energy spent on evaporating excess moisture.

The results obtained are consistent with data from other researchers who note the existence of an optimal moisture range for sorghum grain before popping.

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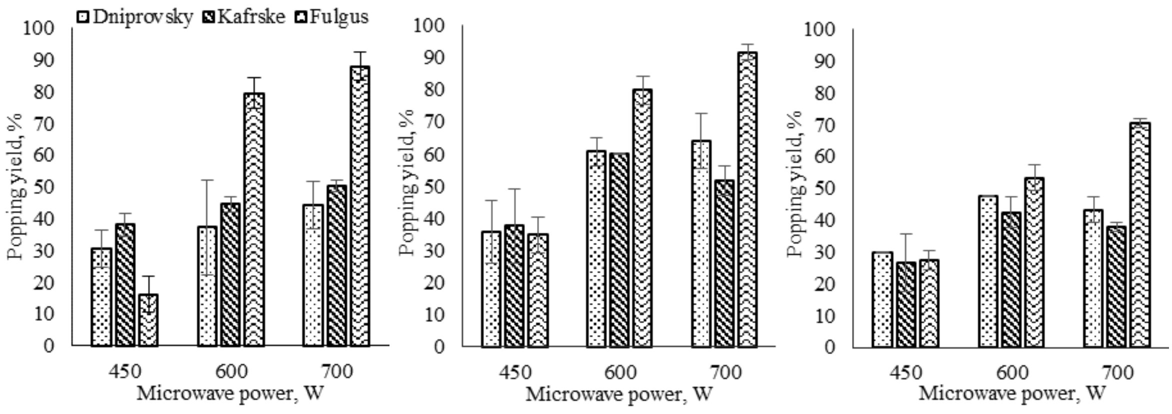

a b c

Fig. 1 – Influence of moisture content and microwave power on popping yield of sorghum grain, %: 13 (a), 15 (b), 17 (c)

According to Mishra et al. [11], as well as Nakade et al. [15], the highest popping yield is achieved at a grain moisture content of about 14-16 %. In this case, both insufficient and excessive moisture content negatively affect the kernel-rupture process. This pattern is explained by the need to ensure an optimal ratio between the amount of water involved in generating internal vapor pressure and the energy expended on its evaporation.

This pattern was most pronounced at a microwave treatment power of 700 W, when the most favorable conditions for realizing the popping ability of sorghum grain were provided (Fig. 1). The maximum popping yield was recorded for the Fulgus variety, which at 15 % moisture content and 700 W microwave treatment power reached 92 %. For the Dniprovsky and Kafrske varieties, under similar conditions, popping yield reached 64 % and 52 %, respectively. The results obtained confirm the significant influence of both grain moisture content and microwave treatment power on popping process efficiency.

The established positive relationship between microwave treatment power and popping yield is also consistent with the results of researchers [12,16], who showed that increasing the intensity of energy input promotes a more complete realization of the popping ability of sorghum grain and increases popping yield.

Thus, for the grain of the sorghum varieties studied, the most effective formation of popped grain occurred at 15 % moisture content and 700 W microwave treatment power. This mode was adopted as the baseline for further comparison of the popping ability of the grain of the studied varieties.

Influence of sorghum varietal characteristics on MW-popping efficiency

It is known that the popping ability of cereal crops is largely determined by the anatomical structure of the kernel, the ratio of corneous to floury endosperm, the physico-mechanical properties of the hulls and other genetically determined varietal characteristics [9, 14]. Therefore, evaluating varietal differences is an important stage in developing the technology for producing popped sorghum and makes it possible to identify the most promising raw material for further technological studies.

For a comprehensive evaluation of MW-popping efficiency, popping yield, bulk density of popped grain and the expansion ratio of the native grain were determined. These indicators characterize, respectively, the efficiency of realizing the grain's popping ability, the degree of porous structure formation and the intensity of kernel expansion during microwave treatment. The study was carried out using the rational process parameters established at the previous stage. The results of the study are presented in Fig. 2.

Analysis of the results shown in Fig. 2 revealed that the varietal characteristics of sorghum grain noticeably affect the efficiency of the MW-popping process and the quality of the resulting product. The studied varieties differed significantly in popping yield, bulk density and expansion ratio. The popping yield results obtained indicate substantial differences in the ability of kernels of different varieties to realize their popping ability during microwave treatment.

A similar pattern was observed for the bulk density of popped grain. The lowest bulk density was characteristic of the Fulgus variety and amounted to about 69kg/m^3, while for the Dniprovsky and Kafrske varieties this indicator was about 105 and 115 kg/m^3, respectively. A decrease in bulk density indicates the formation of a more developed porous structure and a higher degree of kernel expansion during popping.

The expansion ratio was also maximum for the Fulgus variety and amounted to 11.0. For the Kafrske and Dniprovsky varieties, this indicator was 10.7 and 8.0, respectively. Higher expansion ratio values indicate a more intensive increase in kernel volume during MW-popping and the formation of a product with better structural characteristics.

The results obtained are consistent with data from other researchers who note the decisive influence of varietal characteristics on the efficiency of the sorghum popping process. According to Rooney and Rooney [9], Mishra et al. [11], as well as Golubinova et al. [10], different sorghum genotypes can differ significantly in popping yield and the degree of kernel expansion. The main reasons for such differences are considered to be the anatomical structure of the grain, the ratio of corneous to floury endosperm, hull thickness and the physico-mechanical properties of the pericarp [14].

The advantage of the Fulgus variety in the complex of indicators studied is related precisely to the features of the internal kernel structure, which ensure more

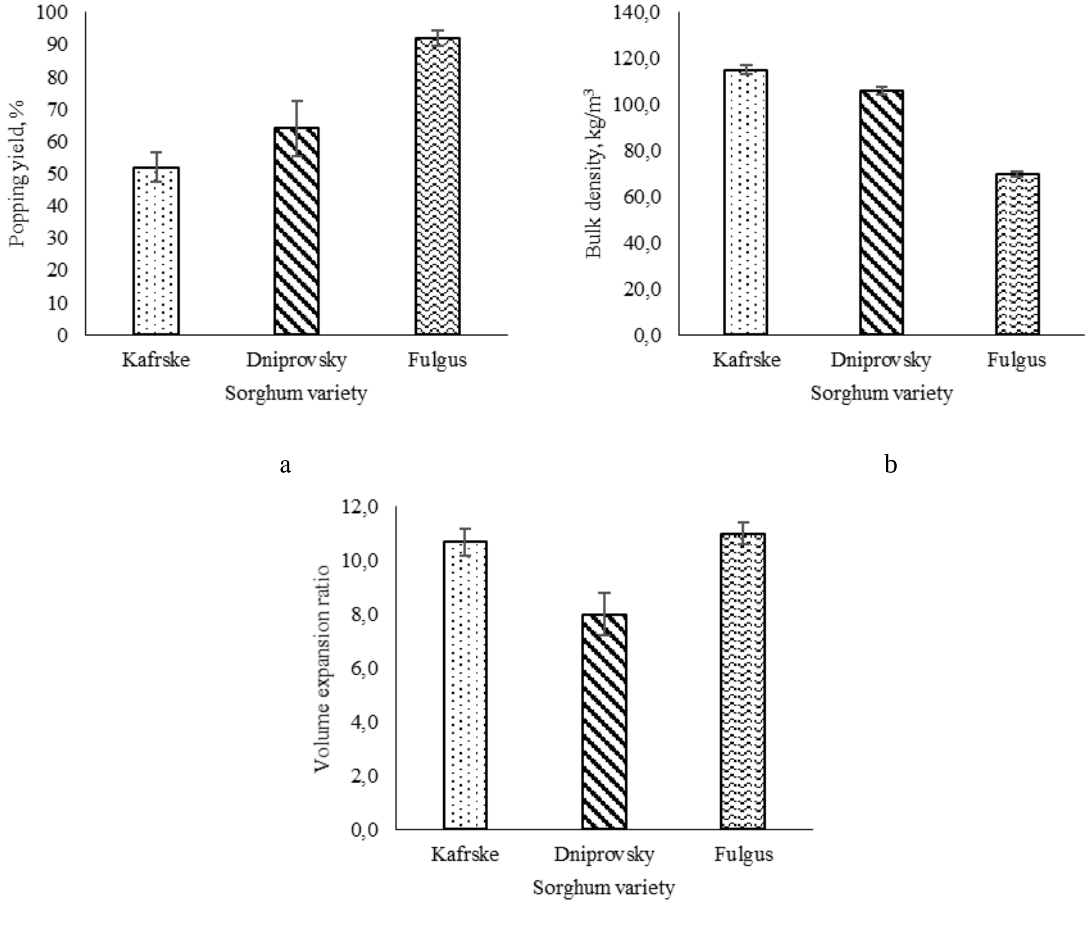

Fig. 2 – MW-popping indicators (grain moisture content 15 %, power 700 W) of sorghum grain of different varieties: a – popping yield, b – bulk density of popped grain, c – expansion ratio of the grain

efficient accumulation of internal water vapor pressure and the formation of a more developed porous product structure during MW-popping [17].

Thus, a significant influence of sorghum varietal characteristics on the efficiency of the MW-popping process has been established. Based on the set of indicators studied, the Fulgus variety showed the best results, providing the maximum popping yield, the highest expansion ratio and the lowest bulk density of popped grain. In view of the results obtained, the Fulgus variety was selected for further study of the influence of grain fractional composition on the efficiency of the MW-popping process.

Influence of grain fractional composition on MW-popping efficiency

The need to study the influence of the fractional composition of the raw material on the efficiency of the MW-popping process is due to the natural heterogeneity of the grain mass in kernel size, which can affect the absorption of electromagnetic energy, heating rate, accumulation of internal pressure and, consequently, the realization of the grain's popping ability.

Analysis of the grain mass revealed significant differences between the studied varieties in size composition. For the Dniprovsky and Fulgus varieties, the share of the coarse fraction was 30.0 % and 26.0 %, respectively, while for the Kafrske variety it did not exceed 1.8 %. Accordingly, the share of the fine fraction was 70.0 % for the Dniprovsky variety, 74.0 % for Fulgus, and 98.2 % for Kafrske. The average kernel diameter of the studied varieties ranged from 3.37 mm for the Kafrske variety to 3.80 mm for the Dniprovsky variety. The results obtained indicate significant heterogeneity of the sorghum grain mass in kernel size, which can affect the course of the MW-popping process and the efficiency of realizing the grain's popping ability.

To test this assumption, a study was carried out on the influence of grain fractional composition on the quality indicators of popped sorghum using a microwave treatment power range of 450-700 W and a grain moisture content of 13-17 %. Grain of the Fulgus variety was used, which, according to the results of the previous stage of the study, demonstrated the best technological indicators. The results of the study are presented in Fig. 3 and Fig. 4.

As can be seen from Fig. 3, the popping yield of sorghum from the fine grain fraction significantly depends on the moisture content of the raw material and microwave treatment power. The lowest values of the indicator were observed at 13 % moisture content, indicating insufficient water vapor formation for effective accumulation of internal pressure in the kernel. Increasing the moisture content to 14-15 % promoted intensification of the popping process and an increase in popping yield. The maximum popping yield of sorghum, namely 76 %, was obtained at 15 % moisture content and 600 W

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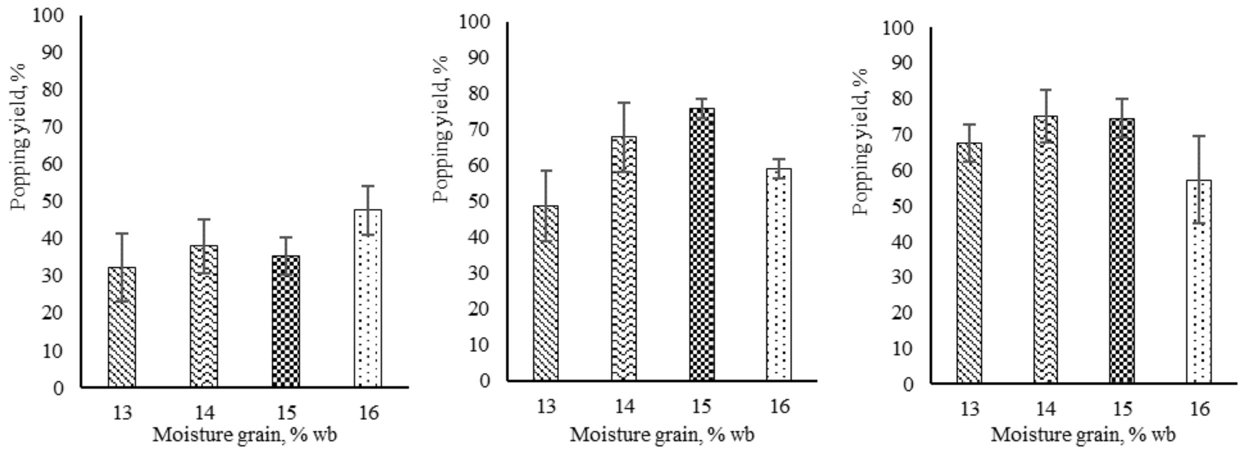

Fig. 3 – Popping yield of sorghum grain from the fine fraction depending on moisture content and microwave treatment power: 450 W (a), 600 W (b), 700 W (c)

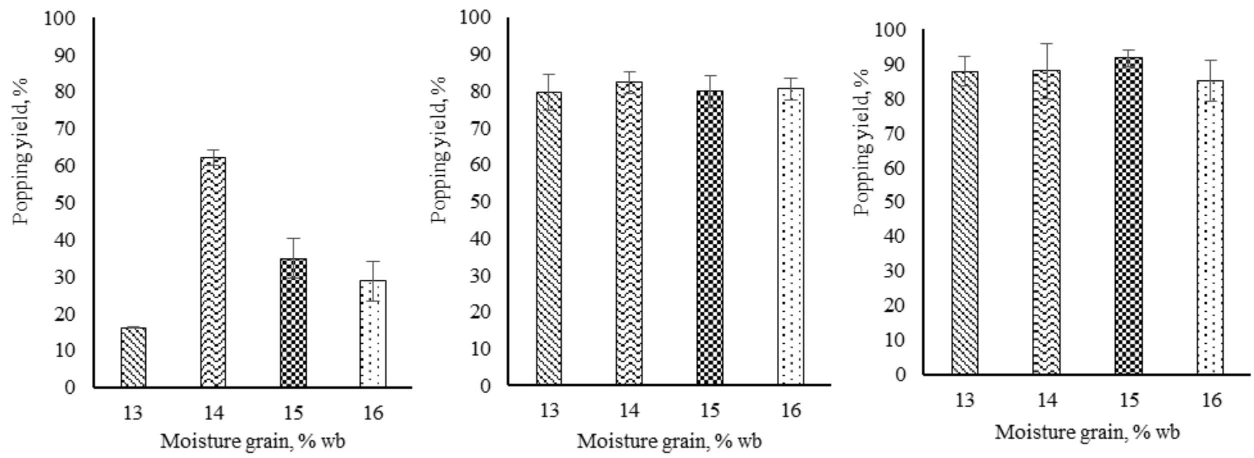

Fig. 4 – Popping yield of sorghum grain from the coarse fraction depending on moisture content and microwave treatment power: 450 W (a), 600 W (b), 700 W (c)

microwave treatment power. A further increase in moisture content to 16 % did not provide additional improvement in results at high power levels, which may be related to excessive energy expenditure on moisture evaporation. The results obtained indicate that for the fine sorghum grain fraction, the most effective treatment modes are 14-15 % moisture content and 600 W microwave treatment power.

According to Fig. 4, it was established that the popping yield of sorghum from the coarse grain fraction also depends on microwave treatment power and the initial moisture content of the raw material. At a power of 450 W, the maximum popping yield was 62 % and was achieved at 14 % moisture content. Increasing the power to 600 W provided a yield of 80-82 % regardless of moisture content, while the best results were obtained at a microwave treatment power of 700 W. Under these conditions, the popping yield of sorghum was 92 % at a grain moisture content of 15 %. The results obtained indicate that for the coarse sorghum grain fraction, the most effective treatment modes are 15 % moisture content and 700 W microwave treatment power.

Visual evaluation of the appearance and signs of thermal damage of the resulting product confirmed the feasibility of a differentiated choice of microwave treatment modes depending on kernel size. For the fine fraction, increasing the power to 700 W was not accompanied by a proportional improvement in product quality and was characterized by signs of local kernel overheating – darkening of the surface and a characteristic taste of thermal damage. At the same time, at a power of 600 W, a product with a light color, uniform structure and pronounced crispness was formed. For the coarse fraction, applying a power of 700 W at 15 % moisture content provided a high popping yield without pronounced signs of overheating.

The results obtained indicate a significant influence of kernel size on the efficiency of the MW-popping process. The coarse fraction was characterized by higher popping yield values compared to the fine fraction under nearly all the treatment modes studied. This may be related to the larger kernel size and differences in the ratio of structural components of the kernel, which affect the course of heating and the accumulation of internal pressure.

Similar patterns have been noted by other researchers. In particular, Cabrera-Ramírez et al. [14] and Mishra et al. [11] report a significant influence of the morphological features of the grain and its size characteristics on sorghum popping efficiency: larger and more uniformly sized kernels are able to provide a higher popping yield and better realization of popping ability.

Thus, it has been established that the fractional composition of the grain significantly affects the efficiency of the MW-popping process and determines the rational modes for its implementation. Whereas for unseparated grain the highest efficiency was provided by the mode of 15 % moisture content and 700 W power, after fractionation, differences in rational treatment parameters were established. For the fine fraction, the most appropriate mode was 14-15 % moisture content and 600 W power, while for the coarse fraction the best results were obtained at 15 % moisture content and 700 W power. Thus, fractionation of grain before MW-popping makes it possible to differentiate the intensity of energy input depending on kernel size, which can contribute to improving the yield and quality stability of popped sorghum.

Conclusions.

A consistent influence of initial grain moisture content and microwave treatment power on the efficiency of sorghum popping was established. For the studied varieties, the highest popping yield was obtained at 15 % moisture content and 700 W power, which allows these parameters to be considered rational for MW-popping of whole grain under the established experimental conditions.

Significant varietal differences in the technological suitability of grain for MW-popping were revealed. The Fulgus variety was characterized by the highest popping yield – 92 %, the maximum expansion ratio – 11.0, and the lowest bulk density of the finished product – about 69 kg/m³, while for the Dniprovsky and Kafrske varieties the popping yield was 64 % and 52 %, respectively. The results obtained provide grounds for considering the Fulgus variety as the most promising raw material among those studied for further MW-popping.

It was established that kernel size determines the manner in which popping ability is realized and the required intensity of microwave treatment. For the fine fraction, the maximum popping yield was 76 % at 15 % moisture content and 600 W power, while for the coarse fraction, at 15 % moisture content and 700 W power, the yield reached 92 %. At a power of 700 W, signs of local overheating were observed for the fine fraction, confirming that it is inadvisable to apply the same treatment mode to grain mass with different kernel sizes.

The established differentiation of rational MW-popping modes by fraction substantiates the feasibility of preliminary fractionation of sorghum grain. Separating the grain mass by size makes it possible to match the intensity of energy input with the size characteristics of the kernels: for the fine fraction, applying 600 W provides a high popping yield without signs of overheating, while the coarse fraction requires increased power of 700 W for effective realization of popping ability. Thus, fractionation should be regarded as a technological raw-material preparation operation that enables differentiated regime control and increases the manageability of the MW-popping process.

Based on the results of the study, it is recommended to apply differentiated MW-popping modes depending on grain size: for the fine fraction – 14-15 % moisture content and 600 W power; for the coarse fraction – 15 % moisture content and 700 W power. The proposed approach makes it possible to take into account the heterogeneity of the grain raw material and creates technological preconditions for improving the stability of yield and structural characteristics of popped grain.

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ВПЛИВ ВЛАСТИВОСТЕЙ ЗЕРНА ТА ПАРАМЕТРІВ НВЧ-ОБРОБКИ НА ЕФЕКТИВНІСТЬ ПОППІНГУ ЗЕРНА СОРГО

Анотація

Дослідження присвячене встановленню закономірностей впливу властивостей зерна сорго та параметрів надвисокочастотної (НВЧ) обробки на ефективність процесу поппінгу. Актуальність роботи зумовлена необхідністю обґрунтування технологічних умов виробництва повітряного зерна сорго та врахування сортових і розмірних особливостей сировини під час вибору режимів НВЧ-обробки. Метою дослідження було встановлення впливу сортових, фізичних і фракційних характеристик зерна сорго, його початкової вологості та потужності НВЧ-обробки на ефективність поппінгу та обґрунтування раціональних параметрів процесу для різних фракцій зерна. Дослідження проводили із зерном сорго сортів Дніпровський, Кафрське та Фулгус, початкову вологість якого змінювали в межах 13-17 %, а потужність НВЧ-обробки – 450-700 Вт за частоти електромагнітного поля 2450 МГц і тривалості обробки 150 с. Ефективність процесу оцінювали за виходом повітряного зерна, об'ємною масою та коефіцієнтом розширення. Встановлено, що для всіх досліджених сортів найвищий вихід повітряного зерна забезпечувався за вологості 15 % та потужності 700 Вт. За цих умов вихід повітряного зерна для сорту Фулгус становив 92 %, Дніпровського – 64 %, Кафрського – 52 %, що підтверджує істотний вплив сортових властивостей зерна на реалізацію поп-властивостей. Сорт Фулгус характеризувався найвищим коефіцієнтом розширення повітряного зерна – 11,0 та найменшою об'ємною масою готового продукту – близько 69 кг/м³, що свідчить про формування найбільш розвиненої пористої структури. Встановлено також істотний вплив крупності зернівок на ефективність НВЧ-поппінгу. Для дрібної фракції найбільш ефективними були режими за вологості 14-15 % та потужності 600 Вт, за яких максимальний вихід повітряного зерна становив 76 %. Підвищення потужності до 700 Вт для цієї фракції супроводжувалося ознаками локального перегрівання. Для крупної фракції найвищий вихід повітряного зерна – 92 % – отримано за вологості 15 % та потужності 700 Вт без ознак перегрівання. Встановлена диференціація раціональних режимів залежно від крупності зернівок свідчить, що фракціонування є не лише операцією механічного калібрування сировини, а технологічним прийомом, який забезпечує узгодження інтенсивності НВЧ-нагрівання з розмірними характеристиками зернівок і дозволяє запобігати перегріванню дрібної фракції при одночасному забезпеченні високого виходу повітряного зерна з крупної. Отримані результати обґрунтовують доцільність попереднього розділення зерна сорго за крупністю перед НВЧ-поппінгом та диференційованого вибору режимів обробки для окремих фракцій, що створює передумови для підвищення стабільності та технологічної ефективності виробництва повітряного зерна сорго.

Ключові слова: зерно, сорго, Sorghum bicolor (L.) Moench; повітряне сорго; повітряні продукти; надвисокочастотна обробка; НВЧ; поппінг; технологічні параметри; фракціонування зерна; вихід повітряного зерна.

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