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PHYSICAL AND MECHANICAL PROPERTIES AND QUALITY INDICATOR OF CORN

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Придатність зерна для промисловості характеризується якістю його як сировини для переробки. Зерно кукурудзи гібридів ДКС 4685×1390 і ПР39Б58 має виражені особливості роду та сорту, відповідає вимогам за зовнішніми геометричними показниками, об'ємом, площею зовнішньої поверхні, сферичністю, питомою і об'ємною масою, об'ємом поверхневих шарів зернівки та масовою часткою крохмальної частини ендосперму, що свідчить про його придатність для переробки.

Ключові слова: *зерно, кукурудза, сорт, фізико-механічні показники, якість.*

Setting of the problem. Indicators of properties of grain can be divided into two groups: properties peculiar to grain of the crop, as well as properties that vary within the same crop. The technical process of grain processing should be improved towards obtaining maximum endosperm, increasing product yield of highest grades and improving their quality [1–5].

Eligibility of grain for industry is characterized by its quality as a raw material for recycling.

Analysis of recent studies and publications. Corn is one of the most common crop plants in the world that surely dominated by the gross harvest of grain. In recent years significantly increased rate of harvesting, storage and export of corn, as well as requirements for quality. Corn is used as a universal culture [2, 5–7].

For grain, as a raw material for processing, its biometric characteristics, size and uniformity of grain mass have the main technological importance [1, 6].

The shape and linear grain size influence the choice of sieves or separators as well as the characteristics of shelling machines. In addition, the geometric characteristics of the grain determines its density when forming the layer and peculiarities of moving grain while transportation. Different from the average, values of grain shape affect the porosity, the angle of repose and the angle of friction. The larger geometric size of grain is, the greater the angle of slope is, which has a positive effect on gravity feed of grains during transportation by gravity pipes. Because of the complexity of the processes, many cereal mills are characterized by a significant extent of processing grain products, which reaches a few kilometres of machines and different mechanisms for average powered plants [6, 8–10].

That is why the study of physical and mechanical properties of grain has not only theoretical but also practical meaning. Given that these properties vary considerably depending on weather conditions, growing technologies and features of varieties, it requires thorough study. In addition, physical and mechanical characteristics of triticale grain have not been studied enough and thus it determines the relevance of the study.

The aim of the research is to study the physical and mechanical properties and quality of corn grain depending on weather conditions and properties of the variety.

Research Methodology. Corn grain DKS 4685×1390 and PR9B58 varieties were grown in the experimental field of the farm "Prolisok+" in Graniv village, Haysyn district of Vinnitsa region.

The study was conducted during 2012–2015 in the Department of technology of storage and grain processing of Uman National University of Horticulture and on the production complex farm "Prolisok +" in Graniv village, Haysyn ditrict, Vinnytsia region.

Linear dimensions were measured for the corn grain by the method described by G. A. Egorov [4].

Grains volume (V) and an external surface area (F) were calculated by the formulas:

$$V = k \bullet a \bullet b \bullet \ell, \text{ mm}^3 \qquad (1)$$

where – a, b, ℓ are width, thickness and length of grain.

k – research coefficient (for corn k=0,50).

$$F = 1{,}12 \times a^2 + 3{,}76 \times b^2 + 0{,}88 \times \ell^2, \text{ mm}^2 \quad (2)$$

Peculiarity of grain form is evaluated by its sphericity, which is the ratio of external surface area equivalent grain bullet (F_{sh}) for up to actual grain area (F):

$$\Psi = \frac{F_{sh}}{F}, \quad (3)$$

Thus: $F_{sh} = 4 \times \pi \times r^2$; $r = 0{,}62 \times \sqrt[3]{V}$

Specific surface of grain was set by the ratio of the area of the outer surface (F) to the volume of grains (V): F / V (4)

The volume of surface layers ($V_{s.l.}$) of grain was determined by the formula:

$$V_{s.l.} = F \times G, \text{ mm}^3 \quad (5)$$

where G is the thickness of tissue (for corn 0,065 mkm).

Mass fraction of starchy endosperm was calculated by the formula:

$$m_e = \frac{V - V_{s.l.}}{V} \times 100 - m_z, \% \quad (6)$$

where m_z is mass of a bud (for corn m_z = 10%).

Specific gravity (density) of grain was determined by the formula:

$$\rho = m/V, \quad (7)$$

where m is mass of grain, g/cm^3.

[4, 6, 8–10].

To determine the quality of the grain standard methods were used: sampling [GOST 13586.3–83; GOST 24104–88]; determination of the color and smell [GOST 10967–75]; contamination [GOST 13586.6–93; GOST 13586.4–83]; debris [GOST 30483–97]; humidity [GOST 13586.5–93]; nature (bulk density)

[GOST 10840–64]; 1000 grain weight [GOST 10842–89]; glasslike structure [GOST 10987–76].

Research results. The geometric characteristics of the grain determine its density when forming layer (porosity) and features of the moving grain during transportation. Because of the complexity of the processes cereal plants are characterized by a significant extent of processing grain products, which reaches a few kilometres of machines and various mechanisms (pneumatic pipes, elevators, conveyors , etc.) for average powered plants [4, 6, 8–10].

10 average-sized grains of corn were selected and their size was measured. According to the conducted measurements, indicators of geometric characteristics of the grain vary rather greatly.

To characterize the geometric features of grain, it is not enough only to specify linear dimensions. The value of volume, area, sphericity, specific surface of grains, specific and bulk density that play an important role in moisturizing, heating and cooling of the grain were determined by the average value of linear dimensions of corn of varieties studied, as well as the volume of surface layers of the grains and mass fraction of endosperm starch which characterize a possible yield of cereals output from such grain (table. 1). The obtained values of physical and mechanical indicators of corn (table 1) are within the limits given in the sources of literature [2, 5, 6, 7]. However, grains of corn of PR39B58 variety have an elongated ellipse shape. So it length, width and thickness respectively by 13,9, 6,2 and 6,0 % higher average data sources relevant literature and by 11,4, 4,9, 7,0 % – the average values of length, width and thickness of corn DKS 4685×1390 variety. Grains of corn of PR39B58 variety grown in 2015 have the largest linear dimensions, grains of DKS4685×1390 variety grown in 2012 have the smallest dimensions.

1. Physical and mechanical properties of corn grain

Variety	Year	Size, mm			Grains volume, V, mm^3	Sphericity, φ	External surface area, F, mm^2	Specific surface of grain, F/V	Volume of surface layers, $V_{s.l.}$, mm^3	Mass fraction of starchy endosperm m, %	Specific gravity (density), ρ, г/см^3	Bulk density, kg/dm^2
		length, ℓ	width, a	thickness, b								
DKS 4685 × 1390	2012	10,30	7,60	4,50	176,10	0,65	234,20	1,30	15,22	81,3	1,20	0,74
	2013	10,70	7,80	4,80	200,30	0,66	252,10	1,26	16,39	81,8	1,19	0,75
	average	10,50	7,70	4,65	188,20	0,65	243,15	1,28	15,80	81,5	1,20	0,74
PR39B58	2014	11,90	7,90	4,60	216,20	0,63	274,07	1,27	17,81	81,8	1,18	0,70
	2015	11,80	8,30	5,40	264,44	0,60	309,33	1,17	20,11	82,4	1,14	0,70
	average	11,85	8,10	5,00	240,32	0,61	291,70	1,22	18,96	82,1	1,16	0,70
According to literature sources*		5,50–13,50	5,00–11,50	2,50–11,50	167,00–232,00	0,58–0,80	192,40–243,40	1,00–1,40	12,51–15,82	78–90	1,16–1,23	0,68–0,82
		10,20	7,60	4,70	180,40	0,68	228,00	1,10	14,82	81,8	-	0,73
LSD 5%		*0,56*	*0,40*	*0,24*	*10,70*	*0,03*	*13,37*	*0,06*	*0,88*	*4,09*	*0,06*	*0,04*

*Note. * – according to [2, 5, 6, 7]: above the line – the border; below the line – average.*

Values of volume and area of the outer surface of corn grain of DKS 4685×1390 and PR39B58 varieties exceed the average data of sources of literature respectively 22–25 % and 4–6 %.

The value of corn is spherical, slightly inferior average of literature sources and made 0,60–0,66. It characterizes corn of DKS 4685×1390 and PR39B58 varieties as being elongated features.

Specific surface of grains was determined by the ratio F/V. This indicator is extremely important in grain drying because it is responsible for the intensity of the heat exchange and moisture diffusion in the grain. The value of this indicator for corn is 1,17–1,30 and exceed the average literature data for this crop.

It is obvious that with decreasing grain size decreases ratio value of volume and area of the outer surface; therefore, small grains should have a higher content of shells and smaller content of the endosperm.

Furthermore, cereals and flour are obtained by means of endosperm and coat, aleurone layer and embryo should be sent in by-products and waste. It is therefore important to have information about the content in the grain endosperm of the parties and the amount of surface layers of the grains to make a prediction about the possible yield of the product.

By most calculations determined the largest mass fraction of starchy endosperm in the grain of corn DKS 4685×1390 variety of 2013 and PR39B58 variety of 2014 at 81,8 % (table 1).

More valuable is processing the grain of corn DKS 4685×1390 variety, since it has a low volume of surface layers – 15,22–16,39 mm^3, while the PR39B58 – 17 % more.

The highest value of bulk density was determined in the grain of corn of DKS 4685×1390 variety – 0,79 kg/dm^2.

Specific gravity (density) of the grain as a whole describes chemical composition, structure, fullness, hardness, strength, maturity of the grain and has a great impact on productive properties. Starch and minerals have the highest specific mass, therefore with the increase of their share density of grains increases, and, conversely, increased protein and lipid lower the density of grain. The value of this index (table 1) of corn of DKS 4685×1390 variety – 1,20 g/cm^3, which is 3 % higher than the average of the PR39B58 variety.

The quality of the finished product depends on the quality of raw materials. Study of grain quality showed that the samples have smell and taste typical for crop.

Technological properties of grain are a combination of features and indicators of its quality which characterize the state of grain in processing and production processes and affect the yield and quality of the product.

Table 2 present comparative characteristic of technological properties of corn grain of the varieties studied. The grain of corn meet typical of confirming their suitability for processing in the rump. Research results of studies of technological grain quality indicators (table 2) showed that corn varieties studied meet the quality standards. Thus, moisture of corn is 13,8–14,9 %, which is 0,1–1,2 % fewer limits of humidity.

2. Characteristics and quality standards of corn grain

Indicator	The actual quality of corn grain						*LSD 5%*	Permissible limits (DSTU 4525:2006) [11]
	DKS 4685×1390			PR39B58				
	year							
	2012	2013	average	2014	2015	average		
Typical composition	VII тип			III тип			-	I–VIII типи
Moisture, %	14,8	14,9	14,8	14,8	13,8	14,3	*0,73*	not more 15,0
Grain impurities, %:	3,5	3,1	3,3	5,3	5,3	5,3	*0,22*	not more 7,0
damaged grains	0,8	0,4	0,6	0,9	0,9	0,9	*0,04*	1,0
sprouted grains	-						-	2,0
Waste impurities, %:	1,4	1,1	1,3	1,9	1,6	1,8	*0,08*	not more 2,0
spoiled grains	0,8	0,5	0,7	0,7	0,6	0,6	*0,03*	not more 1,0
mineral	-	0,1	0,05	-	-		-	0,3
harmful	-	0,1	0,05	-	-		-	0,2
Contamination by pests, units of live specimens	not found						-	not allowed in addition to mite infestation level 1
Weight of 1000 grains, g	214,8	240,4	227,6	255,1	301,4	278,3	*12,65*	210–360*
Nature, g/l	737	746	740	700	700	700	*36,00*	680–820*

*Note. * – according to literature sources [2, 5, 6, 7].*

Content compliance of impurities with grain quality standards demonstrates its thorough cleaning. The total content of waste impurities in the grain of corn DKS 4685×1390 variety and PR39B58 is 35 and 10 % lower than minimum standards, while spoiled grains – 30 and 40 % respectively. In turn, the grain impurities content in the corn grain of indicated varieties, on average during the years of research is 3,3 and 5,3 %, and damaged grains – 0,6 and 0,9 % respectively, which are included in the permissible limits.

In the grain of corn PR39B58 variety not was found sprouted grains and minerals and harmful. In turn, in the grain of corn DKS 4685×1390 variety of 2013 defined by 0,1 % mineral and harmful that are within tolerance.

In the specimens studied no pests were found.

With the increase of vitrescence of grain there is a higher protein content and better technological properties. Yield of cereals and flour from with high vitrescence is larger. Samples of the grain investigated had floury endosperm with vitrescence of corn grain is 30 %.

Weight of 1000 grains of corn of PR39B58 variety was 278,3 g (advantage of grain of 2015 harvest) on average during the years of the research which is more than in grains of DKS 4685×1390 variety by 50,7 g (advantage of grain of 2013 harvest). Grain-unit of corn grain was 700–750 g/l.

Conclusion. Thus, comparing the geometric parameters of corn it was found

that grain of DKS 4685×1390 and PR39B58 varieties have the elongated shape. Large linear dimensions are found in the corn grain of PR39B58 variety.

There was a tendency of changes in the geometric characteristics of the grain of the varieties studied under the influence of weather conditions of the year of study. Significant difference in physical indicators of grains of different growing years was recorded in the corn grain of DKS 4685×1390 variety in terms of thickness, volume, area of the outer surface; PR39B58 – thickness, volume, area of the outer surface, volume of surface layers.

Corn grain of DKS 4685×1390 and PR39B58 varieties has marked peculiarities of type and variety, meets the requirements in terms of external geometric parameters, volume, area of the outer surface, sphericity, specific and volume weight, volume of surface layers of grains and mass fraction of endosperm starch, indicating its suitability for processing.

Technological properties of corn grain are high enough. Grain moisture, content of waste and grain impuritiess are within acceptable standards.

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Аннотация

Осокина Н.М., Костецкая Е.В., Герасымчу к О.П., Евчук Я.В.
Физико-механические и качественные показатели зерна кукурузы

Исследование проведено в течение 2012–2015 гг. на кафедре технологии хранения и переработки зерна Уманского НУС и производственном комплексе фермерского хозяйства "Пролисок+" в с. Гранов Гайсинского района Винницкой области.

Цель исследования – изучение физико-механических и качественных свойств зерна кукурузы в зависимости от условий погоды и особенностей сорта.

Пригодность зерна для промышленности характеризуется качеством его как сырья для переработки. Сравнивая геометрические параметры зерна кукурузы определено, что зерно гибридов ДКС 4685 × 1390 и ПР39Б58 имеет удлиненную форму. Большие линейные размеры определены в зерне кукурузы гибрида ПР39Б58.

Зерно кукурузы гибридов ДКС 4685×1390 и ПР39Б58 имеет выраженные особенности рода и сорта, соответствует требованиям по внешним геометрическими показателями, объемом, площадью внешней поверхности, сферичностью, удельной и объемной массой, объемом поверхностных слоев зерна и массовой долей крахмальной части эндосперма, что свидетельствует о его пригодности для переработки.

Наблюдалась тенденция изменения геометрических характеристик зерна гибридов, что изучали под влиянием погодных условий года исследования. Существенную разницу по физическим показателям зерна разных лет выращивания зафиксировано в зерне кукурузы гибрида ДКС 4685×1390 по величине толщины, объема, площади внешней поверхности; ПР39Б58 – толщины, объема, площади внешней поверхности и объема поверхностных слоев зерна.

Технологические свойства зерна кукурузы достаточно высоки. Влажность зерна, содержание примесей находятся в пределах допустимых норм.

Ключевые слова: *зерно, кукуруза, сорт, физико-механические показатели, качество.*

Annotation

Osokina N.M., Kostetska K.V., Gerasymchuk O.P., Yevchuk Y.V.
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Corn grain of DKS 4685×1390 and PR39B58 varieties has marked peculiarities of type and variety, meets the requirements in terms of external geometric parameters, volume, area of the outer surface, sphericity, specific and volume weight, volume of surface layers of grains and mass fraction of endosperm starch, indicating its suitability for processing.

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Key words*: grain, corn, variety, physical and mechanical properties, quality.*

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ВМІСТ ТА БАЛАНС МІКРОЕЛЕМЕНТІВ І ВАЖКИХ МЕТАЛІВ У ҐРУНТІ ПІСЛЯ ТРИВАЛОГО ЗАСТОСУВАННЯ ДОБРИВ У ПОЛЬОВІЙ СІВОЗМІНІ

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Наведено результати досліджень зміни вмісту рухомих сполук мікроелементів та важких металів у чорноземі опідзоленому важкосуглинковому за різних доз добрив і систем удобрення в польовій сівозміні. На основі даних тривалого стаціонарного досліду і на основі результатів досліджень виявлено, що внесення добрив змінює вміст мікроелементів і важких металів у ґрунті. Розрахунок умовного балансу показав, що переважної більшості мікроелеметів він є дефіцитним. Обґрунтовано доцільність застосування нетоварної частини врожаю як додаткового джерела мікроелементів для рослин

Ключові слова: *мікроелементи, важкі метали, умовний баланс, мінеральні добрива, органічні добрива, тривале застосування добрив.*