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PHYSICAL AND MECHANICAL PROPERTIES AND QUALITY INDICATOR OF BARLEY

Abstract. *The study has been conducted during 2011–2015 in the Department of Technology of storage and grain processing of Uman National University of Horticulture and on the production complex farm «Prolisok+» in the village of Graniv, Haysyn ditrict, Vinnytsia region. The aim of the research is to study the physical and mechanical properties and quality of barley grain depending on weather conditions and properties of the variety.*
Studies of eligibility of certain varieties of barley grain for the use in the processing industry is new.
Barley grain of Zvershennya, Komandor and Svagor 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.
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 barley grain of Zvershennya variety in terms of external surface area, specific surface and volume of surface layers; Komandor – thickness, volume and specific surface; Svagor – volume.
Large linear dimensions are found in the barley grain of Svagor variety.
Keywords: *grain, barley, variety, physical and mechanical properties, quality.*

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ФІЗИКО-МЕХАНІЧНІ ТА ЯКІСНІ ПОКАЗНИКИ ЗЕРНА ЯЧМЕНЮ

Анотація. *Дослідження проведено впродовж 2011–2015 рр. на кафедрі технології зберігання і переробки зерна Уманського НУС та виробничому комплексі фермерського господарства «Пролісок+» в с. Гранів Гайсинського району Вінницької області.*
Мета дослідження – вивчення фізико-механічних та якісних властивостей зерна ячменю залежно від погодних умов і особливостей сорту.
Дослідження придатності зерна ячменю певних сортів для використання в переробній промисловості є новим.
Зерно ячменю сортів Звершення, Командор та Свагор 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.
Спостерігалась тенденція зміни геометричних характеристик зерна ячменю сортів, що вивчали під впливом погодних умов року дослідження. Істотну різницю за фізичними показниками зерна різних років вирощування зафіксовано в зерні ячменю сорту Звершення за величиною площі зовнішньої поверхні, питомої поверхні й об'єму поверхневих шарів зернівки; Командор – товщини, об'єму, питомої поверхні; Свагор – об'єму.
Більші лінійні розміри визначено в зерні ячменю сорту Свагор.
Ключові слова: *зерно, ячмінь, сорт, фізико-механічні властивості, якість.*

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ФИЗИКО-МЕХАНИЧЕСКИЕ И КАЧЕСТВЕННЫЕ ПОКАЗАТЕЛИ ЗЕРНА ЯЧМЕНЯ

Аннотация. *Исследование проведено в течение 2011–2015 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 ячменя в зависимости от условий погоды и особенностей сорта.
Исследование пригодности зерна ячменя определенных сортов для использования в перерабатывающей промышлености является новым.
Зерно ячменя сортов Свершение, Командор и Свагор имеет выраженные особенности рода и сорта, соответствует требованиям по внешним геометрическими показателями, объемом, площадью внешней поверхности, сферичностью, удельной и объемной массой, объемом поверхностных слоев зерновки и массовой долей крахмальной части эндосперма, что свидетельствует о его пригодности для переработки.
Наблюдалась тенденция изменения геометрических характеристик зерна ячменя сортов, что изучали под влиянием погодных условий года исследования. Существенную разницу по физическим показателям зерна разных лет выращивания зафиксировано в зерне ячменя сорта Совершение по величине площади внешней поверхности, удельной поверхности и объема поверхностных слоев зерновки; Командор – толщины, объема, удельной поверхности; Свагор – объема.
Большие линейные размеры определены в зерне ячменя сорта Свагор.
Ключевые слова: *зерно, ячмень, сорт, физико-механические показатели, качество.*

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].

Studies of eligibility of certain varieties of grain for use in the processing industry is new. In addition, there are no recommendations for triticale grain production for the moment. Eligibility of grain for industry is characterized by its quality as a raw material for recycling.

Analysis of recent studies and publications. Barley – one of the oldest cultures. In Ukraine barley grown four to five thousand years BC. Barley is widely used by man for food, feed and industrial purposes [6, 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 and flour 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 barley grain depending on weather conditions and properties of the variety.

Research Methodology. Barley grain of Zvershennya and Komandor varieties were grown on the experimental field of educational research and production department of Uman National University of Horticulture, while barley of Svagor variety was grown in the experimental field of the farm «Prolisok+» in Graniv village, Haysyn district of Vinnitsa region.

The study was conducted during 2011–2015 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 grain of barley 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 barley k=0,58).

$$F = 1{,}12 \times a2 + 3{,}76 \times b2 + 0{,}88 \times \ell 2, \text{ mm}^2 \qquad (2)$$

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

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

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):

$$F/V \qquad (4)$$

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

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

where G – the thickness of tissue (for barley 0,085 mkm).

Mass fraction of starchy endosperm was calculated by the formula:

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

where m_z – mass of a bud (for barley m_z = 2,5%).

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

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

where m is mass of grain, g/cm^3. [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 [8–10].

10 average-sized grains of barley 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 barley 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 wheat and triticale (table 1) are within the limits given in the sources of literature [2, 5, 6, 7]. The grains of barley variety of Zvershennya averages linear dimensions almost coincided with the corresponding average values of literature sources. However, the grains of barley of Komandor, the average for the years of research, the width and thickness of the grains is 0,1 mm larger, and the length is 0,3 mm less than the corresponding mean values from literature sources slight advantage grown in 2014.

In turn, the grains of variety of Svagor the length, width, thickness were respectively 9,6, 3,4, 3,0 mm, an increase of 10–26% of the corresponding mean values of sources and literature at 13–23% and 8–30% average data the grains of barley of Commandor and Zvershennya varieties respectively.

For grains of barley of Svagor variety value and volume of external surface area accounted for 49,9 mm3 and 129,1 mm2 respectively, more average values of literature sources respectively 1,9 and 1,4 times.

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 barley is – 2,56–4,20 and exceed the average literature data for corresponding crops except barley of Komandor and Svagor varieties

all the years of study (table 1).

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 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.

It is estimated that in the barley variety Zvershennya 63,3% starch of the endosperm, while in grades Komandor and Svagor to 6–12% more.

The volume of surface layers of grains of barley during the years of study varied within 7,62–11,08 mm3 (table 1). Among the varieties studied, grains of Svagor variety (10,87–11,08 mm3) had the highest figure and Komandor variety had the lowest figure (30% less).

The highest value of bulk density was determined in the grain of barley of Svagor variety –0,64 kg/dm2.

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 highest value of specific gravity was determined in the grain of barley of Komandor variety – 1,30 g/cm3, while for Zvershennya and Svagor varieties – 1,5 and 14,6% less, respectively (table 1).

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 crops.

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 barley grain, of the varieties studied.

Determined that the value of barley grain humidity 6–10% less than the allowable upper limit. Total waste impurities content in the grain barley varieties Achievements matches the permissible limit, and barley varieties Commander and less Svahor admission rules 35 and 25% respectively. In turn, admixture grain barley varieties accomplishments, and Commander Svahor, average years of research, is 2,5, 3,3 and 2,8%, part of the permissible limits. Content compliance standards of quality grain impurities evidence of a thorough cleaning.

Weight of 1000 grains of barley varieties Commander was 32,6–37,6 g (with preferred grain in 2014), while class

Table 1

Physical and mechanical properties of barley grain

Variety	Year	Size, mm			Grains volume, V, mm³	Sphericity, φ	External surface area, F, mm²	Specific surface of grain, F/V	Volume of surface layers, $V_{s.l.}$, mm³	Mass fraction of starchy endosperm, m_e, %	Specific gravity (density), ρ, г/см³	Bulk density, kg/dm²
		length, ℓ	width, a	thickness, b								
Zvershennya	2011	8,9	2,6	2,1	24,3	0,43	93,8	3,86	7,97	64,7	1,29	0,62
	2012	8,8	2,6	2,1	24,1	0,44	101,1	4,20	8,59	61,8	1,28	0,61
	average	8,8	2,6	2,1	24,2	0,43	97,5	4,03	8,28	63,3	1,28	0,61
Komandor	2013	8,4	2,6	2,3	25,1	0,46	89,6	3,57	7,62	67,2	1,30	0,63
	2014	8,4	2,8	2,5	29,4	0,47	90,9	3,09	7,73	71,2	1,28	0,62
	2015	8,4	2,8	2,4	28,2	0,48	92,5	3,28	7,86	69,6	1,31	0,64
	average	8,4	2,7	2,4	27,6	0,47	91,0	3,30	7,74	69,3	1,30	0,63
Svagor	2014	9,7	3,5	3,0	50,9	0,52	130,3	2,56	11,08	75,7	1,10	0,64
	2015	9,6	3,4	3,0	48,9	0,50	127,9	2,62	10,87	75,3	1,12	0,65
	average	9,6	3,4	3,0	49,9	0,51	129,1	2,59	10,98	75,5	1,11	0,64
According to literature sources*		7,0–10,0	2,0–3,0	1,7–3,0	12,0–45,0	-	58,5–131,9	-	4,97–11,21	62–69	1,13–1,28	0,54–0,70
		8,7	2,6	2,3	26,0	0,45	94,1	3,62	8,00	67,0	-	-
LSD 5%		*0,45*	*0,15*	*0,13*	*1,70*	*0,03*	*5,30*	*0,16*	*0,45*	*3,81*	*0,06*	*0,03*

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

Table 2

Characteristics and quality standards of barley grain

Indicator	Permissible limits (1 class) (DSTU 3769–98) [11]	The actual quality grade										HIP_{05}
		Zvershennya			Komandor				Svagor			
		year										
		2011	2012	average	2013	2014	2015	average	2014	2015	average	
Moisture, %	not more 14,5	13,4	13,8	13,6	13,0	13,0	13,5	13,2	12,6	13,6	13,1	*0,66*
Waste impurities, %:	not more 2,0	2,0	2,1	2,0	1,1	1,3	1,6	1,3	1,9	1,1	1,5	*0,08*
- mineral admixture	not more 0,3	-										
Grain impurities, %	not more 7,0	2,8	2,2	2,5	3,4	3,5	3,0	3,3	2,8	2,8	2,8	*0,15*
Contamination by pests, units of live specimens	not allowed in addition to mite infestation level 1	not found										
Nature, g/l	no less 600	615	606	610	630	624	640	631	635	645	640	*31,80*
Weight of 1000 grains, g	20–55*	31,3	30,8	31,1	32,6	37,6	36,9	35,4	54,8	54,8	54,8	*2,02*

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

achievements – 30,8–31,3 g (with preferred grain in 2011), in its all for variety Svahor this figure corresponded to 54,8 g (30–40% and 43–44% more than corn varieties Commander and Achievements respectively). Nature is indicated barley varieties was 606–645 g/l.

Barley does not apply to crops hulled because determination of films for the culture is not mandatory standards and is not standardized. However, we found that plivchastist barley is 10,9–12,2%, which corresponds to the source literature (10–13%) [6, 7].

In the specimens studied no pests were found.

Conclusion. Thus, comparing the geometric parameters of barley it was found that grain of Zvershennya variety has the most elongated shape and grain of Svagor variety has prevailing linear dimensions. It should be used while preparation of grain for processing as well as the selection of sieves, machines and speed of rotation of their working bodies.

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 barley grain of Zvershennya variety in terms of external surface area, specific surface and volume of surface layers; Komandor – thickness, volume and specific surface; Svagor – volume.

Large linear dimensions are found in the barley grain of Svagor variety.

Barley grain of Zvershennya, Komandor and Svagor 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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