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CHANGE OF STRESS CRACK IN CORN KERNEL DURING ITS PREPARATION FOR PROCESSING

Abstract

The article presents the results of the study of the influence of stress crack in corn kernel on the change of its mechanical properties, namely, on the strength of kernel and its ability to grind during the technological process of preparation for processing. The research was conducted at the Dnipro Food Concentrates Plant.

It is established that percentage of damage, i.e. grain impurities and foreign material (impurities), when receiving grain at the production elevator is within the norms of State standards of Ukraine (DSTU 4525:2006) – up to 7 % and not more than 1.0 %, respectively. But in the process of grain transportation this index is increasing. The maximum level of grain impurities (9.1 %) in corn grain can be observed before its preliminary cleaning on the separator BSH-100, then this indicator decreases significantly to 1.8 % in the cleaned grain, but then increases again in the technological process. Moreover, before sending grain into the degerminator the level totals 4.8 % - almost as much as when receiving grain from vehicles. One can say the same regarding the level of foreign material. Its minimum amount in the grain after pre-cleaning (0.5 %), and the maximum – at the end of the cleaning stage (7.4 %), which is much more than when receiving grain.

The increase in the amount of broken grain (including that relating to impurities) in the technological process is accompanied by higher number of stress cracks in the corn kernel. During receiving, the studied grain has already had a high stress crack – 68 %. At the same time, there was more corn kernel with one crack (41 %). After transportation by a belt conveyor and the main high-performance bucket elevator, although the total stress crack increased not significantly – up to 75 %, but there were changes in the number of cracks: the number of kernels with one crack decreased to 22 %, but the number of kernels with many (three or more) cracks increased from 8 to 33 %, respectively. During further transportation and processing of corn kernel, the stress crack increased to a maximum value of 78 % (before separation on SAD-10-01), and then decreased to 72 % in the grain entering the degerminator.

It is established that the decrease in corn kernel strength is influenced by both the total stress crack and its nature, i.e. the number of stress cracks in each kernel. The maximum required force for the corn kernel damage was observed exactly for grain entering the intake pit – 3.6 kg / 50 kernels. Here you can find more corn kernels stressed by only one crack (single) – 41 % or without cracks – 32 %. And the minimum effort – 3,0 kg / 50 kernels - for cleaned grain after conveyor and elevator No. 1, where the share of kernels with multiple stress crack (3 or more cracks) totaled 43 % (only 22 % of kernels were without cracks). A high inverse correlation of -0.84 was established between the number of stressed kernels with three or more cracks and the effort to break corn kernel.

Based on research, it is recommended to use the index of stress crack in corn kernel to assess its quality when accepted for further processing, as this indicator is directly related to the yield of finished products.

Key words: *corn, corn kernel, stress crack, mechanical properties, percentage of damage*

Introduction

Today, corn grain ranks first in the gross grain crop. So, the study of its mechanical properties and the factors that determine them, as well as changes in the properties of grain during storage, transportation, processing, is relevant.

Mykola Kyrpa's research established that there is too great loss of corn grain in the process of its storage in the wet state, during drying, cleaning, placement, various conditioning, storage in the post-harvesting period. At the stage of harvesting and post-harvest processing of wet grain, the losses are approximately 14-20 %, depending on the technology and material and technical base; for dry grain – 3.4-6.9 % [1].

The level of grain damage, foreign grain and foreign material, in the process of harvesting corn depends on many factors, such as the method of harvesting and grain moisture, the state of sowing and harvesting equipment, varietal characteristics of the hybrid. In most cases, when harvesting cob corn, the total percentage of grain damage (mechanical and thermal) does not exceed 15-17 %, depending on the moisture and the botanical group of corn. When harvesting corn kernel the damage significantly increases (up to 60 %), there is a significant amount of broken grain (up to 5-20 %) [1].

Increased volumes of corn production cause higher operating modes of harvesting and post-harvest processing. In addition, the drying of grain at high temperatures can reduce specific energy consumption by 15-20%, so it is widely used in practice. At the same time, due to rapid moisture evaporation, the percentage of stressed kernel increases to 70-80 %. As a result, its strength decreases and the content of broken grain increases during its movement, loading and unloading.

You should also take into account the different moisture-yielding ability of different types of corn – dent, flint, sweet, in the drying process. Sweet and dent corn give off moisture faster than flint. As a result, they are less damaged during drying, their stress crack is 18-40% less. Therefore, it is recommended to use milder drying regimes for grain of high humidity and early forms of ripeness of flint type of corn [1, 2].

Thus, corn kernel, due to its hardness and glassy nature, is characterized by high stress crack, which certainly affects its structural and mechanical properties [1, 3–5]. Therefore, it is easy to assume that in the process of grain receiving, drying, transportation, cleaning, the content of fine kernels in the grain mass of corn increases, but this assumption is still not sufficiently studied.

Materials and methods

In order to study the change in the content of broken grain and its stress crack at different stages of the technological process of its acceptance, storage and cleaning, they run the analysis of its mechanical properties at the Dnipro plant of food concentrates. For analysis, they took the samples of corn grain at the characteristic "critical" points of the technological schemes of the elevator and groats mill: 1 – Grain entering the intake pit; 2 – Grain after the belt conveyor; 3 – Grain after bucket elevator № 1 (el.); 4 – Cleaned grain after the separator BSH-100; 5 – Cleaned grain after bucket elevator №4 (el.) and scales; 6 – Cleaned grain after conveyor and bucket elevator № 1 (mill); 9 – Main grain before degerminator.

During the testing, the corn grain of type V was processed: semi-dent yellow (yellow or orange color; the shape is transitional from dent to flint with a slightly depressed kernel tip or without indentation/depression). The analysis of quality indicators (grain impurities, foreign material), distribution by size fractions was performed in accordance with DSTU 4525:2006 [6] and GOST 30483-97 [7]. The sieves with holes Ø 8.0; 4.5 and 2.5 mm were selected for this analysis: the sieves Ø 8.0 mm and Ø 4.5 mm received the fraction of the main corn grain – large and small kernel, respectively, and Ø 4.5 mm – broken and wrinkled corn kernel (except for other foreign grain and material).

Corn stress crack was determined according to the USDA method [8]. 100 whole kernels were selected from the samples, which have no visible damage. Each corn kernel was examined for cracks. All stressed kernels were divided into 3 groups: kernel with one stress crack; with double stress cracks; with multiple stress cracks (Figure 1).

In order to determine the effect of stress crack on the reduction of kernel strength, they measured kernel breaking force using a breaking machine with a maximum load of 50 kg. For inspecting, they took whole grains in a row from the general weighing batch (without determining the stress crack percentage) in the amount of 50 pcs. and crushed on a bursting machine with a constant loading speed.

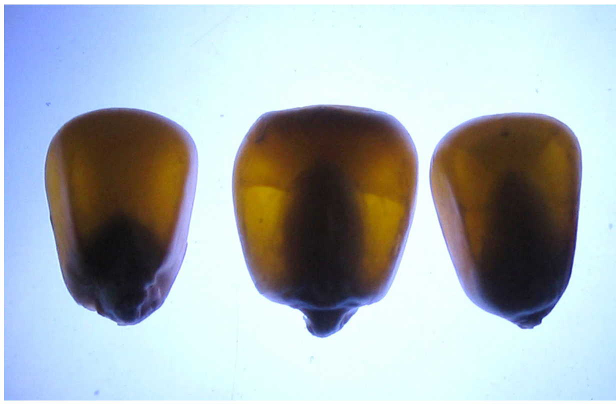
A B C

Fig. 1 – Corn kernel:
A – kernel without cracks; B – kernel with double stress cracks; C – kernel with multiple stress cracks (three or more)

Results and discussion

The Table 1 and Figure 1 shows the results of the analysis of corn kernel quality indicators at different stages of the technological process.

The data show that the amount of grain impurities and foreign material when receiving grain at the production elevator is within the norms of DSTU 4525:2006 – up to 7 % and not more than 1.0 %, respectively. But in the process of grain transportation they increase. The maximum level of grain impurities (9.1 %) in corn grain is observed before its preliminary cleaning on the separator BSH-100, then it significantly decreases to 1.8 % in the cleaned grain, but then increases again in the process, and before the degerminator this level totals 4.8 % – almost as much as when receiving grain from vehicles (this does not apply to individual fractions of products 7 and 8, which after their separate processing are combined before being sent to the degerminator).

The same applies to the level of foreign material. Its minimum amount in the grain is after pre-cleaning (0.5 %), and the maximum – at the end of the cleaning stage (7.4 %), which is much more than when receiving grain. The largest increase in foreign material is observed after grain fractionation in the pneumatic separator SAD-10-01 due to damage of lighter corn kernels. The total number of damaged kernels (together mainly in the basic grain and foreign grain) in the light fraction (trays 3 and 4) reaches a maximum value of 87.7 %, on the contrary, for the heavier fraction – a minimum value of 22.4 %.

The increase in the number of broken kernels in the technological process is accompanied by an increase in the number of stress cracks in the corn kernel (Figure 3). The inspected grain already had a high stress crack percentage when receiving to plant – 68 %, which is obviously due to suboptimal modes during its harvesting and post-harvest processing. At the same time, the largest share accounted for corn kernel with single stress crack (41 %). After transportation by a belt conveyor and the main high-performance bucket elevator, the total stress

Table 1 – Indicators of corn kernel quality at different stages of the technological process

Sample No.	Basic grain, %			Grain impurities, %	Foreign material, %
	total	large –/Ø8.0	fine Ø8.0/Ø4.5		
1	95.1	72.0	23.1	4.3	0.6
2	94.1	69.0	25.1	5.1	0.8
3	88.6	73.6	15.0	9.1	2.3
4	97.9	79.4	18.5	1.6	0.5
5	97.0	77.8	19.2	1.8	1.2
6	93.7	72.9	20.8	4.6	1.7
7	97.8	85.8	12.0	0.8	1.4
8	48.4	10.4	38.0	20.3	31.3
9	87.8	70.4	17.4	4.8	7.4

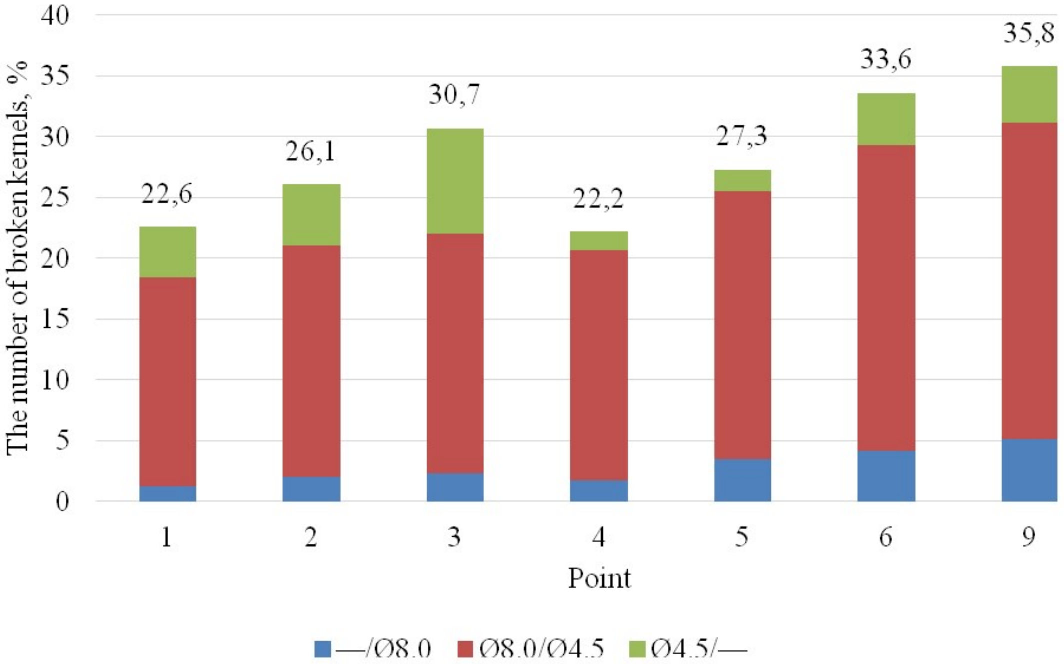

Fig. 2 – The number of broken kernels by fractions in corn kernel at different stages of the technological process:
A – in large grain; B – in fine grain; C – in grain impurities

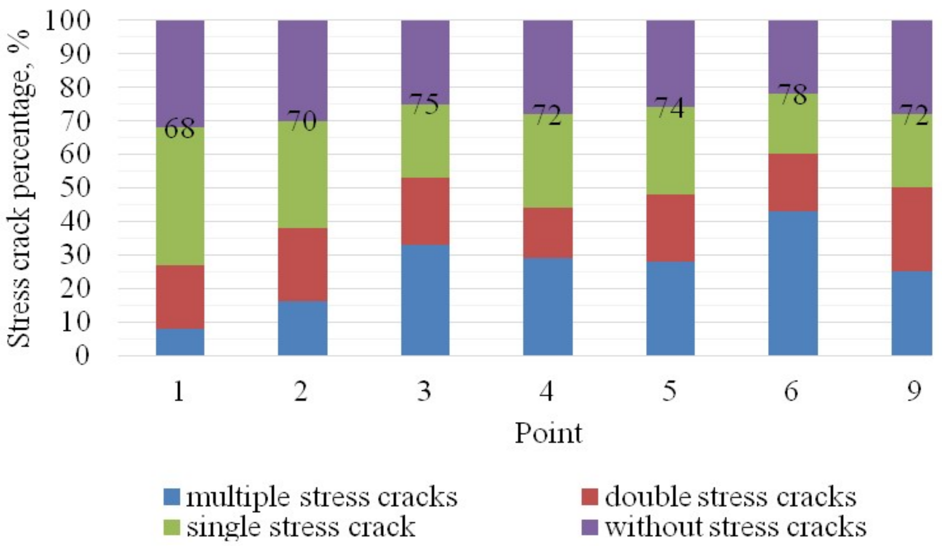

Fig. 3 – Stress crack percentage of basic grain at different stages of the technological process:
A – multiple stress cracks (three or more); B – double stress cracks (two); C – single stress crack;
D – without stress cracks

crack percentage did not increase significantly – up to 75 %, but there were changes in the number of stress cracks: the number of kernels with single stress crack decreased to 22 % (at point 3 – before pre-separation) and increased number of kernels with multiple (three or more) stress cracks – from 8 to 33 %. During further transportation and processing of corn grain, the stress crack percentage increased to a maximum value of 78 % (at point 6 – before separation on SAD-10-01), and then decreased to 72 % in the grain entering the degerminator (point 9). It can be explained by the fact that when the kernel was divided into heavy and light fraction on this separator, a part of the basic grain (mainly in the light fraction) with multiple stress cracks (two or more) was broken.

When analyzing the effect of stress crack on the reduction of grain strength (Table 2), it was found out that the transportation of corn kernel and its processing on the technological equipment leads to changes in both total stress crack in corn kernel and an increase in the total number of stress cracks, which together affects the ability of corn kernel to damage. The maximum required force for corn kernel damage is observed for point 1 (grain entering the intake pit) – 3.6 kg / 50 kernels, where corn kernels with single stress crack – 41 % or without stress cracks – 32 % dominated, and the minimum required force for corn kernel damage – 3.0 kg / 50 kernels were observed for point 6 (cleaned grain after conveyor and bucket elevator No. 1 to SAD), where 43% were grains with multiple stress cracks (3 or more) (only 22 % of kernels were without cracks).

Table 2 – Strength of corn grain at different stages of the technological process

Sample No.	Damage force, kg / 50 corn kernels		
	min	max	average
1	1.4	6.5	3.6
2	1.3	6.6	3.5
3	1.0	6.2	3.5
4	1.3	6.3	3.4
5	1.2	6.1	3.5
6	0.9	5.5	3.0
7	1.3	6.5	3.4
8	1.1	6.2	3.1
9	0.9	5.8	3.5

The correlation analysis of stress crack percentage and damage force showed a high direct relationship between the number of kernels with single stress crack and the minimum and average required force to damage the kernel – 0.62 and 0.76, respectively. On the contrary, with an increase in the number of kernels with multiple stress cracks (three or more), the damage force decreases, i.e. an inverse correlation is established between these indicators – -0.84. But the correlation of the total stress crack with the corn damage force (reverse) is average – -0.45, i.e. the ability of the kernel to damage is more influenced by the nature of the stress crack, rather than its overall value. It is clear that for the inspected samples of corn kernel from different stages of the technological process, there is a very high inverse correlation – -0.93 between the number of kernels with single stress crack and the number of kernels with multiple stress cracks (three or more). It indicates that the mechanical action of transport and technological equipment causes the increase in number of stress cracks in each kernel.

CONCLUSIONS

When studying the technological (mechanical) properties of corn kernel, we found out that its stress crack is an important indicator of quality, which must be taken into account when receiving corn grain for processing. Due to its structure, after harvesting and post-harvest processing, stress crack in corn kernel reaches 70-80 %, which reduces the strength of the kernel and leads to an increase in the amount of broken grain (damaged kernels) in the process of receiving and preparing grain for processing. Also during the technological process the total stress crack in corn kernel increases as well as its nature changes, i.e. the number of stress cracks in each kernel: the number of kernels without cracks or with single stress crack decreases by increasing the number of kernels with multiple stress cracks (three or more). All this leads to lower kernel damage force, i.e. impaces on the yield of finished products: cereals, groats, groats for production of corn curls etc. Therefore, based on research, it is recommended to use the index of stress crack in corn kernel to assess its quality when receiving for further processing.

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ЗМІНА ТРІЩИНУВАТОСТІ ЗЕРНА КУКУРУДЗИ ПРИ ЙОГО ПІДГОТОВЦІ ДО ПЕРЕРОБКИ

Анотація

У статті наведено результати дослідження впливу тріщинуватості зерна кукурудзи на зміну його технологічних властивостей, а саме, на міцність зерна та його спроможність подрібнюватись у ході технологічного процесу підготовки зерна до переробки. Дослідження проведені на Дніпровському комбінаті харчоконцентратів.

Встановлено, що кількість зернової та сміттєвої домішок при прийомі зерна на виробничий елеватор находяться в межах норм ДСТУ 4525:2006 – не більше 7 % та не більше 1,0 %, відповідно, але у процесі транспортування зерна збільшуються. Максимальний рівень зернової домішки (9,1 %) у зерні кукурудзи спостеріга-

ється перед його попереднім очищенням на сепараторі БСХ-100, потім цей показник суттєво зменшується до 1,8 % у очищеному зерні, але далі знову збільшується по ходу технологічного процесу, та перед направленням зерна у дежермінатор складає 4,8 % – майже стільки ж, як при прийомі зерна з автотранспорту. Це же стосується і рівня сміттєвої домішки. Її мінімальна кількість у зерні після попереднього очищення (0,5 %), а максимальна – в кінці етапу очищення (7,4 %), що значно більше, ніж при прийомі зерна.

Зростання кількості битого зерна (у т.ч. того, що відноситься до домішок) по ходу технологічного процесу супроводжується зростанням кількості тріщин у зерні кукурудзи. При прийомі досліджено зерно вже мало високу тріщинуватість – 68 %, при цьому в ньому більшу кількість складало зерно кукурудзи з однією тріщиною (41 %). Після транспортування стрічковим конвеєром та основними високопродуктивними норіями елеватору хоча загальна тріщинуватість зросла не суттєво – до 75 %, але відбулися зміни у кількості тріщин: зменшилось кількість зерен з однією тріщиною до 22 %, але зросла кількість зерен з багатьма (три та більше) тріщинами – з 8 до 33 %, відповідно. При подальшому транспортуванні та обробці зерна кукурудзи тріщинуватість зростала до максимального значення 78 % (перед сепаруванням на САД-10-01), а потім зменшилась до 72 % у зерні, що поступає на дежермінатор.

Встановлено, що на зменшення міцності зерна впливає як загальна тріщинуватість, так і її характер, тобто кількість тріщин у кожній зернівці. Максимальне необхідне зусилля для руйнування кукурудзи спостерігалось для зерна, що поступає у завальну яму, – 3,6 кг/50 зерен, у який превалюють зерна кукурудзи тільки з однією тріщиною – 41 % або без тріщин – 32 %, а мінімальне зусилля – 3,0 кг/50 зерен – для очищеного зерна після транспортеру та норії № 1, у який 43 % складали зерна з 3-ма та більш тріщинами (без тріщин було тільки 22 % зерен). Між кількістю зерен з трьома або більше тріщинами та зусиллям на руйнування зерна кукурудзи встановлено високий зворотний кореляційний зв'язок – -0,84.

На підставі досліджень, рекомендовано використання показника тріщинуватості кукурудзи для оцінки його якості при прийомі на подальшу переробку, так як цій показник прямо пов'язаний з виходом готової продукції.

Ключові слова: *кукурудза, ядро, тріщина, механічні властивості, вміст битого зерна.*

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