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Use of laboratory equipment for analysis of external quality of food maize kernel

Marek Angelovič, Michal Angelovič, Ján Jobbágy, Koloman Krištof

ABSTRACT

The purpose of this study was to investigate the influence of the parameters of the grain air-sieve cleaner in laboratory conditions on the external quality of food maize (*Zea mays* L.) kernel in terms of the design for the selection of a suitable sieve mesh for cleaning procedures. The object of the research was maize kernel, variety Pionier P0216, year of cultivation 2019. The available laboratory equipment was used in the study. To evaluate the external quality of food maize kernel, indicators were determined, which were investigated before and after cleaning. An Asus notebook computer with software from Microsoft Windows XP and Ofice 2010 was used to evaluate the measurement results. These results were achieved: an average bulk density of 846.77 kg.m^{-3} was found in the input sample of food maize kernel after harvest, admixtures before cleaning reached an average of 19.1% and impurities of 2.76%, cleanliness of kernels before cleaning averaged 76.9%, the output after cleaning expressed in terms of bulk density reached an average value of 851.15 kg.m^{-3}, admixtures after cleaning reached 0.07% and impurities 4.21%, clean kernels after cleaning reached 94.86% and damage kernels after cleaning decreased slightly by separation of fragments and chipped kernels. In conclusion, it was stated that the laboratory technique for post-harvest treatment of grain is at a high level worldwide. Currently, the issue of post-harvest processing of grain in Slovakia is addressed at an average level. Post-harvest processing and storage of grain in terms of enginery and technological and economic aspects is little researched in the Slovak Republic, so these issues are open to further research.

Keywords: maize kernel quality, laboratory equipment, cleaning, sorting, sieve maize

INTRODUCTION

Prompt and effective identification of harmful factors is important for food safety and protection to prevent foodborne illness. This view emphasises various analytical techniques used to analyse food raw materials, foods, structure, and quality **[1]**. Thus, continuous assessment of food quality and its safety is essential to deal with public health **[2]**. The issue of food safety is currently gaining in importance and is a difficult task for the food industry. The world's population is constantly expanding, which increases the demands on quantity, food quality, and safety. Foods contaminated with biological or chemical agents cause more than 200 diseases **[3]**. Food safety is crucial for public health, from the food industry to distributors, retailers, and consumers. Every year, about 48 million people become ill, about 1.28 million people are hospitalized, and about 3 thousand people die due to consuming harmful foods **[4]**. The main objective of food risk assessment is to maintain their safety concerning public health. Food laboratories exchange their conventional technologies for innovative and modern analytical methods to promote new visions for which they are challenged **[5]**, **[6]**. The nature of the predominant analytical results in food safety is to display accurate information on the relevant official guidelines as accurately as possible without compromising the characteristics of the procedures, such as accuracy, sensitivity, and repeatability **[7]**. Foods consist of nutritionally essential ingredients, including carbohydrates, proteins, fats, vitamins, water and minerals, and fiber, which are necessary for the consumer in terms of nutritional quality. But from consumer health, their health safety is important **[8]**.

It is important to prepare the conditions for maintaining quantity and quality to store grain in warehouses.

It is the vision of every cereal producer to ensure enough food for the population. Farmers need financial investment to cultivate grain. After collection and storage of grain in the warehouse reduces farmers' fears of quality loss. Still, it can also lead to failures due to reduced quality from damaged grain and unsuitable storage conditions **[9]**. Among grain storage losses, maize kernel is estimated to be susceptible to insect damage of up to 3.5% **[10]**. This is generally due to inadequate post-harvest management practices and an imperfectly designed warehousing structure **[11]**. Grain quality is a set of indicators that qualitatively express the effective parameters of a given crop type according to the purpose of use. There is internal and external quality. Internal quality cannot be increased by post-harvest treatment, only maintained. Internal quality can be affected by improper handling, drying, and storage. It can be low-performance aeration, resulting in the so-called "sweat layer", the alternative method of cooling the products or high temperature during hot air drying. Grain handling affects their external quality, carried out on harvesting lines, transport routes, or storage and retrieval from bins **[12]**. Understanding the impact of post-harvest adjustment procedure on grain quality within farming environments should guide farmers on the choice of better intervention steps, if necessary, to decrease spoilage and post-harvest losses and ultimately contribute to food safety **[13]**. Maize agro-growing environments are changing as a result of climate change. As a result, the conditions under which maize kernel is harvested, handled, and stored continue to vary widely, affecting not only the incidence and severity of loss factors **[14]**, **[15]** but also how farmers respond to post-harvest challenges **[16]**. Traditionally, most crop losses have been associated with insect pests. However, a significant part of the total loss, often not quantified, comes from fungal contamination, rot and disease, rodent damage, mechanical injury, and other defects.

Oil damage is associated with the agricultural environment and harvesting and handling practices. For this reason, the collection and handling procedures are crucial for the safety and health of the grain that is ultimately available for household and market consumption **[17]**.

The purpose of this study is to investigate the influence of the parameters of the air-sieve cleaner in laboratory conditions on the external quality of food maize kernel in terms of the design for selecting a suitable sieve mesh for cleaning procedures.

Scientific Hypothesis

1. The correct cleaning and sorting procedure shall obtain the objective result of clean food maize kernel in post-harvest treatment.

2. The shape and dimensions have a decisive influence on the external quality of the cleaning and grading of the maize kernel.

MATERIAL AND METHODOLOGY

Samples

The subject of the research was the food maize kernel.

Animals and Biological Material

The maize kernel was a variety of Pionier P0216, the year of cultivation 2019, which were removed from the cereal combine harvester after harvest.

Instruments

Laboratory technology was used in the research: Wintersteiger LD 350 laboratory grain thresher, OS-01 grain volume measuring device, SLN-3 laboratory sieve sorter, Ohaus Adventures laboratory digital scale, Numerix laboratory grain counter, Pfeuffer HE 50 grain moisture meter, Testovent 4000 anemometer, and Sonet deviation meter.

Laboratory Methods

The influence of the air sieve cleaner parameters on the external quality grain of food corn was investigated by laboratory technique.

To evaluate the external quality of food maize grain, the following indicators were examined before and after cleaning: dimensional and mass characteristics, critical grain flotation rate in the air stream, grain moisture, impurity content, grain purity, thousand kernels weight (TKW), bulk density, and cleaning efficiency.

Bulk density was determined using an M2/1/t instrument (type OS-1) in $g.dm^{-3}$ and subsequently converted to $kg.m^{-3}$.

Thousand kernel weight was determined based on STN 46 0610 from the proportion of pure grains. Five hundred maize kernels were counted twice (two concurrent repetitions) and then weighed. The weight of the test sample is given in grams. The specified number of 500 maize kernels was determined using a certified NUMIREX grain counter.

Impurities were determined according to STN ISO 950 and STN 46 1011-34 from the test sample. A certified SORTIMAT screening device was used. The individual impurity fractions were sieved on sieves with longitudinal rounded holes 1 mm wide and 20 mm long, with circular holes 4.5 mm in diameter (damaged grain) and manually from the test sample. The weight of the individual impurity fractions and the total weight were determined.

Grain moisture was determined with a certified moisture meter Pfeuffer HE 50 repeated three times based on STN ISO 6540.

The cleaning effect is an indicator for determining the quality of cleaning and calculates based on the formula (1):

$$\eta = \frac{Cv - Cp}{100 - Cp} . 100 \, , [\%] \qquad (1)$$

Where:

CV – cleanliness of the cleaned sample; Cp – sample cleanliness before cleaning.

Description of the Experiment

Sample preparation: Samples were taken after harvesting by grain harvester.

Number of samples analyzed: 3 x 1000 g

Number of repeated analyses: 3x

Number of experiment replication: 3x

Design of the experiment: sample processing, analysis of food maize grain before cleaning, cleaning procedure, analysis of food maize grain after cleaning, calculation of cleaning effect.

Statistical Analysis

The SAS package, version 8.2 was used for statistical evaluation of the results. The basic statistical characteristic ($\bar{x}$ – arithmetic mean and *SD* – standard deviation) was used for mathematical-statistical evaluation of measured data. The statistical comparison of the differences in the observed values between the groups depended on the normality of the data distribution. Analysis of variance (ANOVA) was used to determine normality. The base set in each statistical set compared contained 13 statistical units (n <30). The Schefft's with a *p*-value of 0.05 was used to compare the difference between the groups.

Pearson's correlation coefficient (r) was used to test the relationship between the two variables in each group. The value of the coefficient is between -1 and +1. When evaluating the results, Cohen´s **[18]** procedure was chosen: under 0.1 trivial (simple, easy), 0.1 – 0.3 weak, 0.3 – 0.5 medium, over 0.5 strong (0.7 – 0.9 is often reported as very strong and 0.9 – 1 as almost perfect). Microsoft Windows XP and Office 2010 were used for graphical representation of the results.

RESULTS AND DISCUSSION

Evaluation of dimensional and weight characteristics of food maize kernel food maize kernel

Previous studies **[19], [20]** and **[21]** show that hermetic storage technologies are effective at limiting maize damage in storage. Therefore, one might reasonably expect access to an improved storage method to influence storage decisions.

In terms of cleaning and sorting grain, the most important properties of kernels (there are large considerably, width, thickness) as their size directly affects the choice of shape and sieve mesh. Furthermore, the variability of dimensions, i.e., a considerable interval of the respective size, affects the lower yield and the increase of kernels in class 2, in class 3, respectively, and in the waste. The kernels' dimensional characteristics document the crop's dimensions and the options for choosing the shape and the sieve mesh size, which must be selected for quality cleaning and sorting. The observed crop in our case was food maize kernels. To properly investigate and ensure the input parameters of the treated material on the harvesting line, the evaluated material was sampled directly from the threshing floor. Three hundred grains, the dimensions of which were measured, were randomly selected. When determining the dimensions of the maize kernel, variation curves of the chosen distribution feature were constructed from the measured values. Subsequently, the mass characteristic and the critical speed characteristic were performed. The measured maize kernel values are shown in Figures 1, 2, 3, 4 and 5.

The maize kernel dimensions were measured to distribute their relative and cumulative abundance.

Furthermore, the dimensions of the maize kernel were the basis for the correct choice of shape and sieve mesh in the cleaner.

The dimensional variability of the food maize kernels varies. The kernel width ranged from 5.7 to 10.2 mm, with the most dimensional concentration in the range from 7 to 9 mm. The most significant number of food maize kernels in sample in terms of its length ranged from 9.8 to 14.6 mm and in terms of kernel thickness in the range of 3.5 to 6.5 mm.

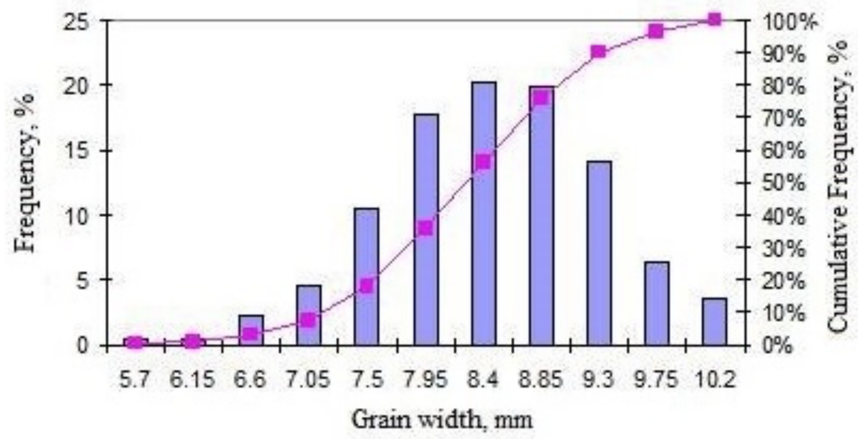

Figure 1 Dimensional characteristics of food maize kernel and cumulative abundance.

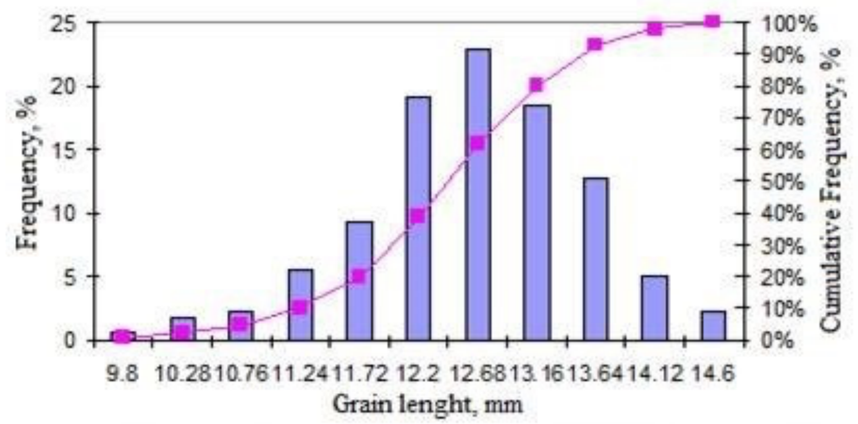

Figure 2 Dimensional characteristics of food maize kernel and cumulative abundance.

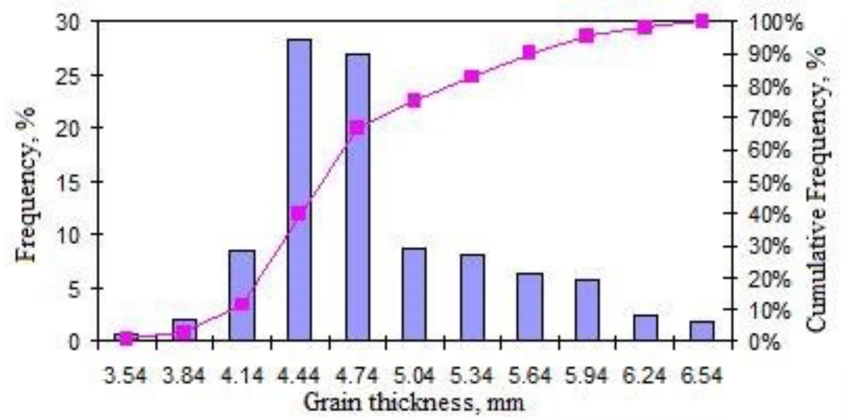

Figure 3 Dimensional characteristics of food maize kernel and cumulative abundance by thickness.

The weight characteristics of the food maize kernel and the cumulative abundance are shown in Figure 4. The weight of the food maize kernels ranged from 0.23 to 0.45 g with an average of 0.31 g. It should be noted that the maize was harvested at a moisture content of 23% to 35%. As a result, the grain weight fluctuated immediately after harvesting.

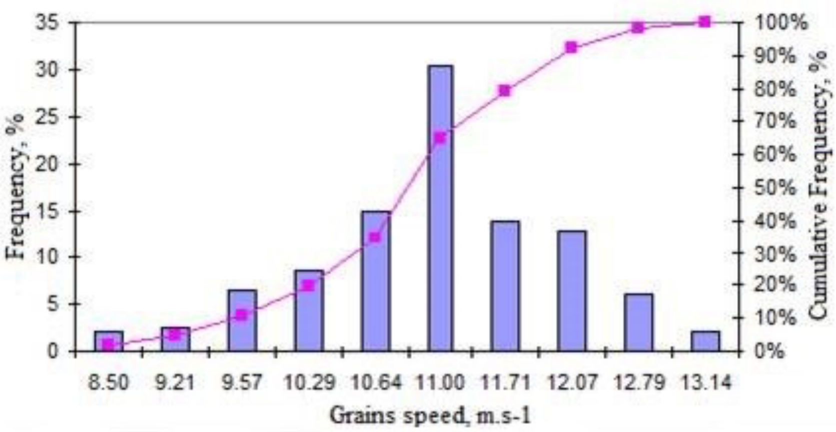

Figure 5 Characteristics of critical speed of food maize kernels and cumulative abundance.

From the point of view of kernel cleaning and sorting, the airflow rate at which the kernel floats and remains in equilibrium is important. This speed is called the lift speed or critical speed. To set the airflow speed in the cleaning machines, laboratory measurements of the given quantities were performed. The results of the measurements are shown in Figure 5. The stated speed was performed on a 4 x 100 kernels sample based on measurements in a modified laboratory grain grader K-293.

Table 1 Statistics on dimensional and weight characteristics of food maize kernels.

	Length, mm	Width, mm	Thickness, mm	Weight, g	Critical speed, m.s^{-1}
n	300	300	300	300	400
Mean value	2.41058	8.248598	4.725837	0.34454	10.9775
Median	12.45	8.29	4.54	0.343	11
Modus	12.01	8.21	4.51	0.351	11
SD	0.928611	0.842691	0.645089	0.05493	0.948812
Variance of selection	0.862318	0.710128	0.41614	0.003017	0.900245
Minimum	7.94	2.32	0.89		8.5
Maximum	16.43	11.84	8.7	0.669	13.5

Note: n – multiplicity, *SD* – standard deviation.

Variation distribution curves were processed for individual kernel samples. Next, a cumulative frequency distribution curve was constructed. In this way, the interval of critical speeds and the number of entrained kernels of the monitored crop were determined. Based on the measured values, the critical rate of buoyancy of the maize kernels in the airstream was determined. For maize kernel samples, a value in the range of 8.6 to 13.6 m.s^{-1} was measured with an average of 10.9 m.s^{-1}.

Subsequently, from the variation curves of the dimensional characteristics of the maize kernel, sieves were designed for the grain cleaner SLN 3 in order to clean.

Table 2 Designed sieves for the kernel of food maize.

Crop	1. Upper sieve (straw)	2. Medium sieve (sandy)	3. Bottom sieve (sorting)	Air speed
Corn	Ø 11.0 mm/12.0 mm	Ø 45.0 mm	Ø 6.0 mm	13.5 m.s^{-1}

Investigation of the influence of air-sieve grain cleaner parameters on external quality grain

The SLN sample grain cleaner is intended for cleaning and sorting seeds, grain of wheat, malting barley, but also other crops such as maize, oilseeds, legumes, as well as more difficult cleanable products such as sunflower, flower and grass seeds, etc. The sieves are fully automatically cleaned using rubber balls. Exchange the sieves are a matter of minutes. The operation is quiet and without shocks (Figure 6).

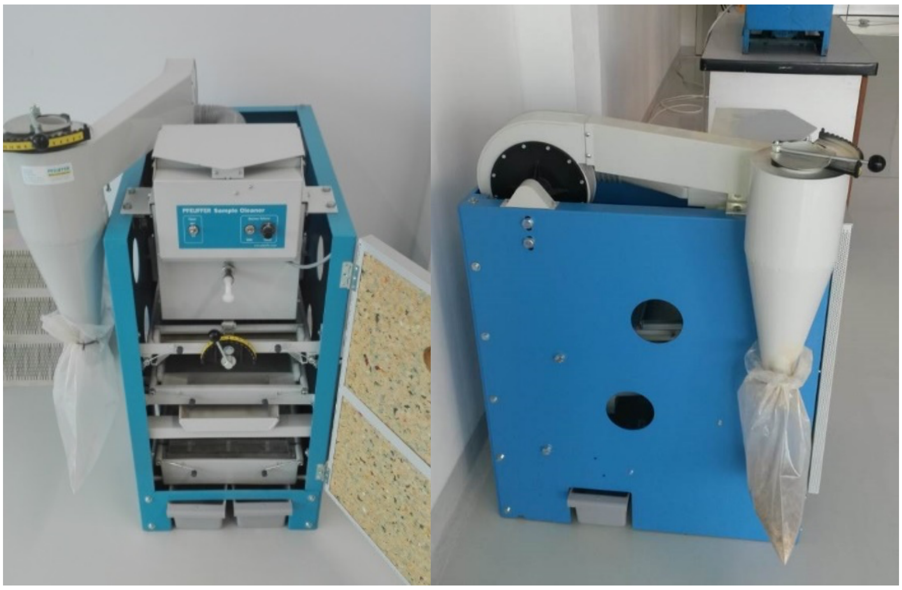

Figure 6 Laboratory air cleaner SLN 3. Note: Source.

Table 3 Technical parameters of laboratory air grain cleaner SLN 3.

Indicator	
Height with cyclone	970 mm
Device heihgt	780 mm
Width with cyclone	580 mm
Width without cyclone	420 mm
Lenght	680 mm
Weight	85 kg
Sample weight	1 kg
Voltage/input power	230 V/0.37 kW
Noise	82/78 dB/A

Evaluation of external quality of food maize kernel, variety Pionier P0216, year of cultivation 2019 in the process of cleaning

Maize intended for use in the food industry must comply with legislative requirementsc**[22]**, **[49]**. It must not contain foreign objects that would pose a problem with its security **[50]**. Maize processors must also implement the HACCP system. In terms of Hazard Analysis and Critical Control Points (HACCP) and food safety, it was necessary to investigate maize kernel's external and internal quality, Pionier variety P0216, year of cultivation, and harvest 2019. System of critical control points, risk analysis, and other quality assurance systems such as the ISO 9000 system can ensure product quality. The ISO 9000 includes standards such as ISO 9001: 2015, ISO 9000: 2015, ISO 9004: 2009, and ISO 19011: 2011 for food hygiene monitoring **[23]**. Table 4 shows the summary results of the investigated quantities of external quality of maize kernel before and after the cleaning process.

Table 4 Evaluation of external quality of food maize kernel before and after cleaning at grain cleaner SLN 3.

Indicator	**Before cleaning** $\bar{x}$ **±*SD***	**After cleaning** $\bar{x}$ **±*SD***	**Analysis of variance**	**Scheffe test**
Bulk density, kg.m^{-3}	846.77 ±32.10	851.15 ±42.71	0.09^{-}	$p > 0.05$
TKW, g	324.47 ±45.85	311.19 ±59.62	0.41^{-}	$p > 0.05$
Impurities, %	9.99 ±2.96	5.14 ±1.64	26.73^{+++}	$p \leq 0.05$
Admixtures, %	0.73 ±0.54	0.36 ±0.40	3.78^{-}	$p > 0.05$
Damaged grain, %	9.26 ±2.83	4.77 ±1.42	26.08^{+++}	$p \leq 0.05$
Clean grain, %	90.01 ±2.96	94.86 ±1.64	26.73^{+++}	$p \leq 0.05$
Grain moisture, %	27.97 ±3.45	28.71 ±4.15	0.24	$p > 0.05$

Note: n = 13 before and the same after cleaning, $\bar{x}$ – mean, *SD* – standard deviation, TKW – thousand kernel weight, $p > 0.05$ – statistically insignificant difference, $p \leq 0.05$ – a statistically significant difference.

Identifying the physical and engineering characteristics of cereal crop grains is very important to optimize the design parameters of agricultural equipment used in their production, handling, and storage processes. So, it is essential to determine and recognize the database of physical and engineering (aerodynamic and mechanical) properties of these agricultural products because these properties play an important role in designing and developing specific machines and their operations such as sorting, separating, and cleaning **[24]**.

Kernel weight is usually represented by 1000-kernel weight. Thousand kernel weight (TKW) is not only directly related to the grain yield and milling quality of grain but also has an impact on the seed vitality and growth, indirectly affecting the yield **[25]**.

Thousand kernel weight was also found to be closely associated with kernel size traits as well, such as kernel length (KL), kernel width (KW), kernel thickness (KT), and the kernel length/width ratio (L/W) **[26]**. As a result, thousand kernel weight is frequently used in grain research as a measurement indicator **[27**].

In the statistical evaluation of the dependent variable maize kernel bulk before and after cleaning, the assumption of a normal distribution of indicator data in groups was observed. The deviations were the same. The variances in these groups were the same, not statistically significant (F 0.09^{-}, *p* >0.05), which confirmed the result of the analysis of variance, which verified the assumption of similarity of variance. The null H0 hypothesis that there was no difference between the groups was rejected.

The maize kernel bulk density reached 846.77 kg.m^{-3} before cleaning and 851.15 kg.m^{-3} after cleaning. The maize kernel bulk density difference before and after treatment was not statistically significant (*p* >0.05). The statistical evaluation showed that the measured maize kernel bulk density values fluctuated more in the group after treatment compared to the measured values before treatment (*SD* 42.71 vs. *SD* 32.10). The bulk density is considered to determine the capacity for cleaning and grading equipment **[24]**. The average value of bulk density was found **[28]** at 790 kg.m^{-3} for maize.

In the statistical evaluation of the dependent variable thousand kernel weight of maize grain before and after purification, the assumption of a normal distribution of indicator data in groups was observed. The deviations were the same. The variances in these groups were the same, not statistically significant (F 0.41^{-}, *p* >0.05), which confirmed the result of the analysis of variance, which verified the assumption of similarity of variance. The null H0 hypothesis that there was no difference between the groups was rejected. Thousand kernel weights of maize grains reached a value before cleaning of 324.47.77 g and after cleaning of 311.19 g. The difference in the thousand kernel weight of maize grain before and after treatment was not statistically significant (*p* >0.05). The statistical evaluation showed that the measured values of thousand kernel weight fluctuated more in the group after cleaning compared to the measured values before cleaning (*SD* 59.62 vs. *SD* 45.85). Grain number and weight are the main components of corn grain yield. If the corn grain yield is reduced, e.g., under the influence of stress drought, you reduce the number and weight of injuries in maturity **[29]**, **[30]**, **[31]**, **[32]**. Water stress during the vegetative growth stage of maize limits the potential yield (grain number) **[33]**, while stress in the reproductive phase mainly affects the increase in grain weight **[30]**.

In the statistical evaluation of the dependent variable maize kernel impurities before and after purification, the assumption of a normal distribution of indicator data in groups was observed. The deviations were the same. The variances in these groups were the same, statistically significant (F 26.73^{+++}, *p* ≤0.001), which confirmed the result of the analysis of variance, which verified the assumption of similarity of variance. The null H0 hypothesis that there was no difference between the groups was rejected. Impurities in corn grains reached a pre-cleaning value of 9.99% and a post-cleaning value of 5.14%. The difference in impurities before and after treatment was statistically significant (*p* ≤0.05). The statistical evaluation showed that the measured values of impurities fluctuated more in the group before treatment compared to the measured values after treatment (*SD* 2.96 vs. *SD* 1.64).

In the statistical evaluation of the dependent variable maize kernel admixtures before and after cleaning, the assumption of a normal distribution of indicator data in groups was observed. The deviations were the same. The variances in these groups were the same, not statistically significant (F 3.78^{-}, *p* >0.05), which confirmed the result of the analysis of variance, which verified the assumption of similarity of variance. The null H0 hypothesis that there was no difference between the groups was rejected. Maize kernel admixtures reached a pre-cleaning value of 0.73% and a post-cleaning value of 0.36%. The difference in pre-treatment and post-treatment admixtures was not statistically significant (*p* >0.05). The statistical evaluation showed that the measured values of admixtures fluctuated more in the group before treatment compared to the measured values after treatment (*SD* 0.54 vs. *SD* 0.40).

In the statistical evaluation of the dependent variable damaged maize kernel before and after purification, the assumption of a normal distribution of indicator data in groups was observed. The deviations were the same. The variances in these groups were the same, statistically significant (F 26.08^{+++}, *p* ≤0.001), which confirmed the result of the analysis of variance, which verified the assumption of similarity of variance. The null H0 hypothesis that there was no difference between the groups was rejected. Damaged maize kernel reached 9.26% before cleaning and 4.77% after cleaning. The difference in damaged grain before and after the cleaning was statistically significant ($p \leq 0.05$). The statistical evaluation showed that the measured values of damaged grain fluctuated more in the group before cleaning compared to the measured values after cleaning (*SD* 2.83 vs. *SD* 1.42). There can be significant differences in the quality of pre-stored grain with regard to insect populations, the amounts of insect-damaged grain, moldy/diseased/discolored grain, shriveled grain, and non-consumable grain **[34]**. Temperature and humidity affect the incidence and multiplication of insects **[35]**, molds **[36]**, and rodents **[37]**. Large quantities of the broken grains promote the spread of insects and microorganisms, and they are therefore not desirable on lots of grain intended for long-term storage **[34]**.

In the statistical evaluation of the dependent variable maize kernel, which should meet the quality requirements of the pure grain, before and after cleaning, the assumption of a normal distribution of indicator data in groups was observed. The variances were the same. The variances in these groups were the same, statistically significant (F 26.73^{+++}, $p \leq 0.001$), which confirmed the result of the analysis of variance, which verified the assumption of similarity of variance. The null H0 hypothesis that there was no difference between the groups was rejected. The pure maize kernel reached a value of 90.01% before cleaning and 94.86% after cleaning. The difference in maize kernel moisture before and after purification was not statistically significant ($p > 0.05$). The statistical evaluation showed that the measured values of pure maize kernel fluctuated more in the group before purification compared to the measured values after purification (*SD* 2.96 vs. *SD* 1.64).

In the statistical evaluation of the dependent variable maize kernel moisture before and after the purification, the assumption of a normal distribution of the indicator data in the groups was observed. The variances were the same. The variances in these groups were the same, not statistically significant (F 0.24^{-}, $p > 0.05$), which confirmed the result of the analysis of variance, which verified the assumption of similarity of variance. The null H0 hypothesis that there was no difference between the groups was rejected. Maize kernel moisture reached a value of 27.97% before cleaning and 28.71% after cleaning. The difference in maize kernel moisture before and after purification was not statistically significant ($p > 0.05$). The statistical evaluation showed that the measured values of maize kernel moisture fluctuated more in the group after purification compared to the measured values before purification (*SD* 4.14 vs. *SD* 3.45). The moisture content of 22 – 25% is considered ideal for efficient harvesting **[38]**, although field drying to ~18% m. c. is sometimes considered sensible to reduce drying costs. Early harvesting was done within the proper timing in the cooler agro-location but was somewhat late in, the warmer agro-location because of rapid dry-down. Maize kernels are considered physiologically mature when the m. c. is 30 – 35% **[39]**. Compared to the drier grain, the wet grain continued to lose moisture, apparently at a faster rate, eventually attaining a lower moisture level **[34]**.

The correlation between the two variables of the examined food maize grain indicators before purification is shown in Table 5 and Table 6.

Table 5 Correlation relation between the two variables of the examined food maize kernel indicators before purification.

Indicator	TKW	Impurities	Admixtures	Damaged grain	Clean grain	Grain moisture
Bulk density	-054^{-}	0.14^{-}	-0.40^{-}	0.22^{-}	-0.14^{-}	-0.40^{-}
TKW		0.06^{-}	0.60^{+}	-0.06^{-}	-0.06^{-}	0.67^{+}
Impurities			0.31^{-}	0.98^{+++}	-1.00^{+++}	0.42^{-}
Admixtures				0.13^{-}	-0.31^{-}	0.73^{++}
Damaged grain					-0.98^{+++}	0.30^{-}
Clean grain						-0.42^{-}

Note: TKW – thousand *kernel* weight, the number in each row of the column – the result of the correlation coefficient (r); +, ++ and +++ superscript for the number – statistically significant relationship between two variables $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$.

The evaluated results of the correlation between the two variables in the food maize kernel before purification statistically confirmed the existence of a strong positive or negative linear dependence or did not statistically confirm a low, medium, and strong dependence. A strong positive linear relation, statistically significant, was recorded between thousand kernel weight and admixtures ($p < 0.05$), between thousand kernel weight and grain moisture ($p \leq 0.05$), between impurities and damaged grain ($p \leq 0.001$), and between admixtures and grain moisture ($p \leq 0.05$), and a strong negative relation statistically significant between impurities and clean grain (0.001) and damaged grain and clean grain

($p \leq 0.001$). The linear relation between the other monitored indicators was not statistically significant ($p > 0.05$).

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Table 6 Correlation relation between two variables of the examined indicators of food maize kernel after purification.

Indicator	TK	Impurities	Admixtures	Damaged grain	Clean grain	Grain moisture
Bulk density	-018^{-}	0.15^{-}	-0.06^{-}	-0.16^{-}	0.15^{-}	-0.01^{-}
TKW		0.33^{-}	0.48^{-}	0.25^{-}	-0.33^{-}	0.51^{-}
Impurities			0.65^{+}	0.97^{+++}	-1.00^{+++}	0.38^{-}
Admixtures				0.46^{-}	-0.65^{-}	0.09^{-}
Damaged grain					-0.97^{+++}	0.43^{-}
Clean grain						-0.39^{-}

Note: the number in each row of the column – the result of the correlation coefficient (r),
+, ++ and +++ superscript for the number – statistically significant relationship between two variables $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$.

The evaluated results of the correlation between the two variables in the food maize kernel after purification statistically confirmed the existence of a strong positive or negative linear or did not statistically confirm a low, medium, or strong dependence. A strong positive linear relation, statistically significant, was recorded between impurities and admixtures ($p \leq 0.05$), impurities and damaged grain ($p \leq 0.001$), and a strong negative linear relation was statistically significant between impurities and clean grain ($p \leq 0.001$) and between damaged grain and clean grain. The linear relation between the other monitored indicators was not statistically significant ($p > 0.05$).

Thus, the relations between post-harvest management practices, storability concerns, and the adoption of improved maize kernel varieties remain poorly understood. Understanding these relationships is important for future maize productivity and food security **[40]** and **[41]**.

Samples of food maize kernel before and after cleaning are shown in Figure 7 and Figure 8.

Figure 7 Maize kernels before cleaning.
Note: Source **[22]**.

Figure 8 Maize kernels after cleaning.
Note: Source **[22]**.

Cleaning efficiency

The cleaning effect (cleaning efficiency) on the investigated maize kernel cleaning operation was good.
The cleaning effect when cleaning the food maize kernel with grain cleaner SLN 3 laboratory technique was, on average, 47.50%, with a fluctuation of measured values of 10.43 (SD). Cleaning of the food maize kernel increased the purity after cleaning with SLN 3 by 4.49%.

Agricultural grain production is seasonal, while demand for agricultural commodities is more evenly distributed throughout the year **[42]**, **[43]**.

In these circumstances, it is necessary to meet the average demand by storing the surplus supply during the harvest period for gradual release to the market during the off-season. For the regular availability of grain or the stabilization of any country's economy, quality cereals must be supplied to consumers for the production of various products and marketing, as well as to farmers for sowing and growing healthy kernels **[44]**.

Understanding the impact of post-harvest operations on grain quality within the contexts of farming environments should guide farmers on the choice of better intervention steps, if necessary, to decrease spoilage and post-harvest losses and ultimately contribute to food security and safety **[45]**. These agro-environments are also becoming increasingly variable due to climate change. As a result, the conditions under which maize is harvested, handled, and stored continue to vary widely, affecting not only the incidence and severity of loss agents **[35]**, **[36]** but also the way farmers respond to post-harvest challenges **[46]**.

Walls et al. **[47]** state in their study that food safety and food quality are, therefore, key **c**omponents of food systems that have a major impact on consumer welfare. Food safety is closely linked to food-borne diseases and involves food handling. Foodborne diseases harm the health of individuals, sometimes entire families, and have a negative impact on societies and, ultimately, nations. Such diseases disrupt people's livelihoods by having a significant impact on healthcare and business networks. The World Health Organization (WHO) has identified health care, which protects people from imminent potential danger, as one of the five key areas of WHO work in the 12th General Work Program **[48]**.

CONCLUSION

The importance of post-harvest grain treatment lies in securing and maintaining the expected state of quality of grain growing. Cereal grain quality is ensured through cleaning, sorting, and drying.
Our research was focused on investigating and evaluating the cleanliness of the food maize kernel and proposing the selection of suitable sieve pans for the laboratory air-sieve cleaner.
Based on the achieved results, we can state that:
- an average bulk density of 846.77 kg.m^{-3} was found in the input sample of food maize kernel after harvest,
- admixtures before cleaning reached an average of 19.1% and impurities of 2.76%,
- cleanliness of kernels before cleaning averaged 76.9%,
- the output after cleaning expressed in terms of bulk density reached an average value of 851.15 kg.m^{-3},
- admixtures after cleaning reached 0.07% and impurities 4.21%,
- clean kernels after cleaning reached 94.86%,
- damaged kernels after cleaning decreased slightly by separating fragments and chipped kernels. From the obtained results, we found that after cleaning, the bulk density and cleanliness of the kernels were higher, but therefore the admixtures and impurities were lower. The grain-cleaning machine meets the required ISO and STN 461100-8 for food maize kernels, where the impurities together in quality class A (standard) are the most 7% and in class B (minimum) to 12%.

Laboratory technology for post-harvest treatment of grain is at a high level worldwide. Currently, the issue of post-harvest processing of grain in Slovakia is addressed at an average level. This work is recommended as a basis for evaluating the inputs of raw materials from primary production for food production. The research results in laboratory conditions can be used to compile technology in large post-harvest lines. The issue of post-harvest processing and storage of grain in terms of enginery and technological and economic aspects is little researched in the Slovak Republic, so these issues are open to further research.

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Contact Address:
*Marek Angelovič, Slovak University of Agriculture, Faculty of Engineering, Institute of Agricultural Engineering, Transport and Bioenergetics, Tr. A. Hlinku 2, 949 76 Nitra,
Tel.: +421 37 641 4363
Email: marek.angelovic@uniag.sk
ORCID: https://orcid.org/0000-0002-5040-0358
Michal Angelovič, Slovak University of Agriculture, Faculty of Engineering, Institute of Agricultural Engineering, Transport and Bioenergetics, Tr. A. Hlinku 2, 949 76 Nitra,
Tel.: +421 37 641 4795
Email: michal.angelovic@uniag.sk
ORCID: https://orcid.org/0000-0001-9562-2547

Ján Jobbágy, Slovak University of Agriculture, Faculty of Engineering, Institute of Agricultural Engineering, Transport and Bioenergetics, Tr. A. Hlinku 2, 949 76 Nitra
Tel.: +421 37 641 4796
Email: jan.jobbagy@uniag.sk
ORCID: https://orcid.org/0000-0003-0204-1036
Koloman Krištof, Slovak University of Agriculture, Faculty of Engineering, Institute of Agricultural Engineering, Transport and Bioenergetics, Tr. A. Hlinku 2, 949 76 Nitra,
Tel.: +421 37 641 4368
Email: koloman.kristof@uniag.sk
ORCID: https://orcid.org/0000-0003-1573-4667

Corresponding author: *