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Post-harvesting corn losses indexes in a storage unit: A case study

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Abstract

The objective of this work was to evaluate the current losses of drying and processing of corn in a unit of reception. The case study consisted of evaluation of machines and equipments, as well as the evaluation of operational procedures adopted by the unit. The methodology was based on determination of the dryer and cleaning machines operational parameters. The results evidenced drying non uniformity and corn losses due to overdrying. It was also observed that corn cleaning increased mechanical damages and consequent breakage of the product, instead of just cleaning it. The average losses due to overdrying were of 1.21 % points and the broken material represented losses in the order of 1.12 % points.

Key words: Breakage; cleaning; over-drying.

Introduction

Several factors can be responsible for losses in a storage unit, including the state of the structures, the grain management, and mainly the lack of training of the operators.

Although in Brazil significant losses are observed in the quality of agricultural products, largely for the operational inadequacy of the systems, there are no researches evaluating the losses due to handling, and in the storage of the grains (Puzzi, 1986).

In spite of being a problem in developing countries, the loss quantification does not receive its due importance by most of those countries. In Brazil, the post-harvesting losses are in the order of 20 % (Lorini, 1993).

The main inconveniences for processing are related to mechanical damages, usually worsened by drying. The damages and/or mechanical injuries are caused by shocks and abrasions of the product with harder surfaces, resulting in broken, crunched, fragmented, scratched and entirely damaged seeds (Fessel, 2003).

Concerning to drying, taking into consideration the common deficiencies in the Brazilian systems and the way they are operated, some criteria of grain quality can be seriously compromised. Among the most frequent problems, shrinkage and grain fissures can be mentioned, what unfortunately lowers the quality of the product.

Another important factor, and little considered in the great majority of the studies, is the control of the exit grain moisture content of the dryers. Such operation is frequently accomplished by people with not enough technical knowledge of the real consequences of such work. As a result, grain with high moisture gradients is sent to storage (Dalpasquale, 2002). The current value of moisture content for commercialization is established as 14 %, for corn, in Brazil. However, variations above and below this value are common, and they bring consequences to the commercial process. If the product is not properly dried, safe storage is jeopardized; if over dried, it represents technical breakage and economical losses.

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As for the broken and/or damaged seed, besides allowing fungi contamination during storage, it loses its economical value (Krabbe, 2000). In the commercialization, the broken ones receive lower value. To increase the value of the product, the broken parts are separated by the cleaning machines, and are subsequently added to the whole product in amounts according to legal standards. That operation is known as a blend.

The cleaning of the product is vital to the drying process, and to the safe storage of the agricultural products. Cleaning is basically conducted by machines that use air through fans and sieves of different sizes and forms for each product (Puzzi, 1986).

The process of cleaning is commonly accomplished in two stages. The first one, the pre-cleaning, is a basic operation to facilitate the transport of the material to and by the elevators, and to rationalize the drying process. The second stage refers to cleaning in a more specific way. In that phase, it is intended to reduce as much as possible the amount of foreign material, and to separate the mass that suffered mechanical injuries up to that stage.

The expected index of foreign materials in the exit of a pre-cleaning system varies between 2 % to 3 %, for good drying operations. After the cleaning machines, the advisable indexes are around 0.5 % to 1 %, for a good storage.

Thus, in order to guarantee the quality of product in all phases, good and concrete measures are needed to allow for the food safety excellence (Profiqua, 1999).

Material and methods

This work was carried out in an Agricultural and Industrial Cooperative, located at the latitude of 23 ° 29' South, longitude 51 ° 47' west and altitude of 670 meters.

The study had the purpose to obtain a general and critical view of the operational procedures currently used by the unit. Favorable and unfavorable points of operation were observed in order to rationalize the unit activities.

The observations concentrated on the drying and cleaning of the product, by comparing the inlet and outlet values of some parameters. The results were extended to the whole amount received by the unit, in order to convert them to economical values.

Drying system

The drying system was evaluated by the following parameters:

Amount of air

A digital anemometer was used to measure the air velocity and the areas at the dryer air entrances.

Drying temperature

The drying air temperature was read in a thermometer of the system.

Temperature of the product

Samples were collected in different points of the drying column, placed in an isolated cup, where a thermometer was left for two to three minutes before reading.

Firewood consumption

The amount of firewood used in the different drying operations was weighted in a proper scale available at the storage unit.

Dryer perfomance

The performance of the dryer was based on the amount of product dried by hour of operation. That amount was determined at the handling system after the dryer.

Overdrying losses

The final moisture content, when lower than the value for marketing indicates losses, because no mass is added by the time of commercialization. Therefore, the overdrying losses for corn are evaluated when the moisture content of the product is lower than 14 %. The following equation is used in such evaluation:

$$OL = [(14 - Mf/(100 - Mf)-1]x100 \quad (1)$$

where,
OL – overdrying losses, %;
Mf – final moisture content of corn, %.

This index describes the breakage percentage for excessive drying, because the final moisture content (Mf) is lower than the one of commercialization. It also indicates how much is lost, only related to mass, when drying is not stopped at proper values. If the final moisture content is higher than 14 %, that value assumes the position of 14 %, and this value is the new final moisture content in equation 1.

Cleaning system

The evaluation of the cleaning system involved the determination of the broken kernel and of the foreign material kept by the machines, in order to determine the efficiency of the system.

Efficiency

The efficiency of the system was determined from the relationship between the percentage of foreign material kept by the machines, and the amount of it at the entrance of the machine.

Performance

The performance of the cleaning system was based on the determination of the amount of product transported by the handling system, by unit time.

Broken kernel

The percentage of broken material was obtained through the weighting of each broken type separated by the machines. The broken ones followed two classifications commercially practiced: the broken parts kept by the sieve 3.5 mm, and the broken ones which passed through that sieve. This procedure was executed in three phases of the process: at the reception, at the cleaning process after drying, and in the expedition of the product.

Results and discussion

The drying tests were accomplished with the dryer operating in full tower and in intermittent regime. The high initial moisture content presented by the product forced the drying to the last option.

Drying

The drying (Table 1) system operated with an average air temperature of 65.7 ºC, which resulted in a product temperature of 34.8 ºC. The parameters are as expected, without jeopardizing the quality of the product, according to recommendations of Portella (2001).

The corn average final moisture content was 13.4 %, which is below the established for commercialization (14 %). As shown in Table 1, considerable variation in the values of final moisture content is observed, characterizing drying non uniformity. The fact happens due to the unloading time: unloading began with the product presenting grain moisture content above the desired value, and finished with product moisture content well below the optimum one. This is done looking for the desirable average moisture content of the product.

The amount of air supplied by the drying system was on the average of 84,357 m^3/hr, corresponding to the sum of the entrances of air of the furnace and cyclone. The amount of air in the exit, measured at the exhausting fan was of 129,600 m^3/h. The measured values are less than the expected ones for systems of this capacity, and the difference in the amounts of entrance and of exit evidences false entrances of air in the system.

The average time for intermittent drying was of two hours and thirty six minutes. In Brazil, it is common to remove around three percentage points of moisture per hour, for corn. Considering the initial moisture content and the observed drying time, the system could accomplish the operation in two hours, without jeopardizing the quality of the product. In practice, a higher amount of air for drying and/or higher drying air temperature could aid in the process.

Table 1. Drying parameters for a corn drying system.

Sample	Inicial moisture (%)	Drying temper. (ºC)	Product temper. (ºC)	Final moisture (%)	Amount of air (m^3/hr)	Drying time (hr)	Wood consumpt. (m^3/hr)	System Efficiency (ton/hr)
SC1		63.00	35.00	15.0				
SC2		63.00	34.00	13.6				
SC3	20.70	65.00	35.00	12.8	82,871	2:30	1.52	18.70
SC4		50.00	33.00	11.7				
SC5		58.00	34.00	13.8				
Average of Operation1	20.70	59.80	34.20	13.4	82,871	2:30	1.52	18.70
SC6		67.00	36.00	15.8				
SC7	20.60	67.00	35.00	13.7	84,661	2:13	1.52	21.37
SC8		70.00	35.00	12.8				
SC9		68.00	35.50	13.0				
Average of Operation2	20.60	68.00	35.38	13.8	84,661	2:13	1.52	21.37
SC10		65.00	37.00	16.5				
SC11		68.00	35.00	14.1				
SC12		70.00	36.00	13.0				
SC13	21.20	67.00	34.00	13.5	84,803	2:50	1.52	16.96
SC14		65.00	33.00	11.8				
SC15		64.00	35.00	11.6				
SC16		67.00	34.00	11.8				
Average of Operation3	21.20	66.57	34.86	13.2	84,803	2:50	1.52	16.96
SC17		70.00	35.00	14.5				
SC18		68.00	36.00	13.2				
SC19	20.10	62.00	34.00	12.2	85,459	2:45	1.52	16.91
SC20		67.00	35.00	12.7				
SC21		65.00	34.00	11.8				
SC22		68.00	35.00	12.2				
Average of Operation4	20.10	66.67	34.83	12.8	85,450	2:45	1.52	16.91
SC23		69.00	33.00	15.7				
SC24		67.00	35.00	13.8				
SC25	20.40	68.00	35.00	14.0	83,978	2:45	1.52	17.38
SC26		65.00	35.00	13.1				
SC27		67.00	34.00	13.0				
SC28		68.00	35.00	12.7				
Average of Operation5	20.40	67.33	34.50	13.7	83,978	2:45	1.52	17.38
Final average	20.60	65.67	34.75	13.3	84,355	2:36	1.52	18.27

Regarding the firewood consumption, the process used 1.52 m^3/h of dried wood. The value is compatible with the consumption demanded by dryers of 40 ton/hr that use around 1.6 m^3/hr, according to Whistles (2006).

The performance of the system is dependent of the drying time and of the working regime. The best performance obtained was of 21.4 ton/hr. In the average, the system dried 18.3 ton/hr. Considering that the system is for 65 ton/hr, it presents a performance well below the expected, even operating at intermittent model. For the intermittence time of 2.45 hours, the performance of the dryer should be of 23.6 ton/hr, which is 5.3 ton/hr more than the obtained value. In other words, the dryer operates with 77.6 % of its capacity.

Cleaning

The analysis of the Table 2 allows verifying that the average moisture content of the product, 12.8 %, differs of the verified at the exit of the dryer. The fact possibly is due to the product being processed hours after drying, allowing the complete cooling of the mass and some additional moisture evaporation.

The percentage of broken material was of 2.9 %, higher than the percentage at the system entrance which was of 2.05 %, indicating that the system is causing damages to the product, instead of just cleaning it.

Table 2. Characteristics of the product and operational parameters of the system for corn cleaning at entrance.

Sample	Product characteristics			Material retained			System
	Moisture (%)	f.m. (%)	Broken (%)	f.m. (%)	Small parts (%)	Broken 3.5 mm (%)	(ton/hr)
L1	12.5	1.20	2.30				
L2	12.0	1.20	2.20	0.28	0.45	2.80	60.3
L3	13.0	0.90	1.80				
L4	12.3	1.00	2.00				
Average of operation1	12.5	1.08	2.08	0.28	0.45	2.80	60.3
L5	13.4	1.00	2.20				
L6	13.0	0.90	2.10	0.29	0.46	2.86	62.5
L7	13.0	0.80	2.20				
L8	12.9	1.10	2.00				
Average of operation 2	13.1	0.95	2.13	0.29	0.46	2.86	62.5
L9	12.5	0.70	2.00				
L10	13.0	0.80	2.10	0.31	0.47	3.02	64.6
L11	12.3	1.00	1.90				
L12	12.7	1.20	2.20				
Average of operation 3	12.6	0.93	2.05	0.31	0.47	3.02	64.6
L13	13.2	0.80	2.10				
L14	13.3	0.90	2.00	0.28	0.44	2.93	61.2
L15	12.7	1.00	1.80				
L16	12.9	1.10	1.90				
Average of operation 4	13.0	0.95	1.95	0.28	0.44	2.93	61.2
Final average	12.8	0.98	2.05	0.29	0.45	2.90	62.2

The best operational condition for the cleaning system was 64.6 ton/hr, with an average of 62.2 ton/hr. This system is composed by two machines of 45 ton/hr capacity each.

In the analysis of the efficiency, the average entrance of broken kernel and foreign materials - f.m. in the cleaning system of 0.98 % must be considered. After cleaning, the small parts of broken kernels are separated from the foreign materials, which make two separate items. Those two items result in 0.74 %, turning the efficiency of the system equals to 75.5 %, an acceptable value for cleaning systems.

Overdrying losses

The technical breakage for overdrying of the product is common in processing units, being conditioned to the way the drying system is operated, to the deficiencies of the labor involved in the system, and mainly to the allegation of the need of appropriate drying for a safe storage.

Excess of drying was verified in all analyzed operations. In extreme situations, the corn was dried to the average of 12.8 % of moisture (operation 4, Table1), or 1.2 percentage points below the moisture of commercialization. The breakage for overdrying, as average, was 0.7 percentage point, because the average corn moisture content was 13.3% at the exit of the dryer. Considering the average product moisture content at the exit of the cleaning system and consequent storage (12.8 %), the breakage at that stage is 1.2 percentage points.

Extending the breakage index to the full capacity of static storage, in the case of 1,100,000 bags, it means that 15,138 bags of corn are lost in the process. That mass, costing R$15.00 per bag, corresponds to losses of R$ 227,064.00 or U$ 100,917.00 (R$ 2.25/U$)

Losses for breakage of the product

At reception, the corn presented 0.93% of broken parts, which passed through the 3.5mm sieve. After drying, that value increased to 2.05%, and 2.9% after cleaning. This latest result indicates a problem with the cleaning system, because the amount of broken material increased instead of reducing. When the product was removed from the storage system, 2.15% of broken corn was present in the mass.

Considering that nº 2 corn can be sold with up to 3 % of broken parts, the inadequate way the cleaning system is operating is causing 1.12 % points of losses to the original material. Corn was received with 0.93 % of broken parts, which increased to 2.9 % after cleaning, indicating 1.97 % points of damage to the product. Because corn can be sold with up to 3 % of broken parts, 0.85 % point of this damaged corn may be added to the product as a blend, after the 2.15 % found at the selling time.

The 1.12 % points of losses of damaged corn, out of 1,100,000 bags turns into 12,320 bags. Using the same economical values as for overdrying, the losses for breakage result in R$ 184,800.00 or U$ 83,133.00.

The broken parts are stored to wait for an opportunity of being blended with sound materials, to aggregate value to those parts. It must be remembered that the broken parts should be transferred to some storage, which involves labor and sometimes chemical treatment, all of them increasing the cost of the product.

Conclusions

The drying system presents low performance, in the order of 18.3 ton/hr, when operating intermittently. Drying submits the product to excessive moisture removal, presenting an average grain moisture reduction of 1.2 % points.

The cleaning system presents 75.5 % efficiency when processing corn. However, it presents low operational performance, in the order of 69.1 % (62.2 ton/hr out of 95 ton/hr nominal capacity). The losses this system added to the product as broken parts, was an average of 1.12 % points.

Both kinds of damages led to R$ 411,864.00 or U$ 184,050.00 of loss, which is a meaningful amount of money to be saved with proper drying and cleaning systems.

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