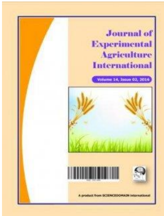

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# Percentage of Corn Grain Losses in Roads Transport Based on Weight of Loads

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Authors PSXP, AB and CC conducted the experiment and wrote the first draft of the manuscript. Authors ARBS, DSP, RSM and FCM discussed the results, correct and improve the writing of the manuscript in Portuguese and English versions. All authors read and approved the final manuscript.*

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## ABSTRACT

Estimates for the 2018/2019 grain crop indicate production in the order of 238.5 million tons, an increase of 4.7% compared to the 2017/2018 harvest. This production, although satisfactory, could still be greater, were it not for the problems faced with the logistics of grain disposal where billions are lost due to the limited investment in infrastructure. The objective of this work is to establish a percentage loss index, as well as to assess these quantitative losses during bulk grain transportation of corn. The research was developed through a partnership between the National Supply Company (CONAB) and the NTA (Nucleus of Storage Technology), at the Federal University of Mato Grosso. It was established the evaluation of losses related to grain

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transportation in the main waterways, being bulk corn in BR 163/364 in the State of Mato Grosso. After the choice of the highways evaluated, we carried out research on the data of romaneios in the transportation of corn in bulk. The obtained data, through the romaneios, provided weight of origin, weight of destination, place of origin and place of destination, in this way, by difference was obtained the quantity of grains lost in the transport and the mileage traveled in each route. By means of these data it was possible to obtain three indices of losses, one in Kg/Km (kilogram per kilometer wheeled), another one in Kg/t (kilograms per tons transported), and also determined an index of loss in percentage of grains transported. With the indication of the indices it was possible to evaluate the losses. The Bitrem truck (7 axles) was used as the basis for calculating the losses, since during the interviews this was the type that had the most occurrences in BRs evaluated, with 39%. Based on the questionnaire, the load weight of 38,000 kg was therefore adopted. For the study of corn grain losses in road transport, 39,642 data were analyzed for routs, with 24,902,808.50 km rotated, mean of 628,19 km away by route. The amount of corn grain transported was 1,852,437,042 kg. The total losses were 1,808,951 kg, averaging 45.63 kg of loss per trip. The loss per km was on average of 0.072 kg. Transport of corn grains between Nova Ubiratã and Rondonópolis presented the highest frequency of trips (8629 trips), however the losses were 37,710 kg of grains or approximately 628 bags of corn (60 Kg). The index of percentage loss for maize (0.1025%). This percentage is lower than the adopted one that is of 0.25%, nevertheless, represent considerable losses for the economy. Based on the data obtained in the present study, it can be stated that it is possible to adopt percentage loss rates of less than 0.25% in contracts. It is recommended to adopt the percentage rates of grain loss in road transport of 0.10% for maize.

*Keywords: Quantification; corn grains; trucks; highway.*

## 1. INTRODUCTION

Estimates for the 2018/2019 grain crop indicate a production in the order of 238.5 million tons, an increase of 4.7% compared to the 2017 /2018 harvest [1]. This production, although satisfactory, could still be greater, were it not for the problems faced with the logistics of grain disposal where billions are lost due to the limited investment in infrastructure, with projects that only aim to cover the existing holes, without expanding and giving better quality of the existing mesh, and still without proposals that aim to reduce displacement that is still based on long distances [2]. Thus, a plot of the graphs is lost in the movement to the ports, which represents about 0.25% loss [3].

According to Pasqua and Lima [4], the loss of grains in transport is observed around roadsides, in the flow of production to the warehouses, due to the precarious state of the roads that are bumpy, without pavements causing breaks in the fleet, as well as increases in freight prices. For [5], it is precisely during transportation in the truck of the granulated load that the greatest losses occur due to body shaking and unsealing of the load. It turns out that a portion of the grains is lost through the gaps between the side and the floor of the body, which can be solved by the inner lining of the same, a practice already adopted by several truckers and manufacturers of bulk bodies. Another considerable portion is lost through the upper part of the body, due to the inadequate and uneven wrapping resulting from manual activity which often requires speed. Obviously, these losses are influenced by the quality of the paving where the truck travels, as the trepidation and the holes are decisive in the grain escape when the load is not completely sealed inside the body.

In this context, road transport losses occur due to a series of factors involving the use of precarious roads, vehicle speed, old trucks and / or with faults in the body, lack of qualification of the driver, types of implements of transport equipment, among other factors [6]. These losses are understood as the difference in weight between origin and destination. The shippers (cargo owners) establish commercial relations for the treatment of loss in contracts with providers of transport services.

This loss or fall in road transport is calculated from an index of 0.25% per tonne of grain transported. This index is the tolerable agreed between origin and destination, when the transport units are weighed and analyzed [7]. However, studies have already shown average levels of losses below acceptable levels and practiced by the market, resulting in losses that can be further reduced by new road transport indices [8].

In view of the above, this work aims to establish an index of loss in percentage, as well as to evaluate these quantitative losses verified during the transportation of corn grain in bulk.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site Description

The research was developed through a partnership between the National Supply Company (CONAB) and the NTA (Nucleus of Storage Technology), at the Federal University of Mato Grosso.

It was established the evaluation of losses related to grain transport in the main runways, being bulk corn in BR 163/364 in the State of Mato Grosso (Table 1).

After the choice of the highways evaluated, data were analyzed on the bulk data of the corn transportation (Figs. 1 and 2).

### 2.2 Obtaining Data

The obtained data, through the romaneios, provided weight of origin, weight of destination, place of origin and place of destination, in this way, by difference was obtained the quantity of grains lost in the transport and the mileage traveled in each route. By means of these data it was possible to obtain three indices of losses, one in Kg/Km (kilogram per kilometer wheeled), another one in Kg/t (kilograms per tons transported), and also determined an index of loss in percentage of grains transported. With the indication of the indices it was possible to evaluate the losses.

The evaluated loads were separated by weight, in this way it was possible to carry out the classification by type of trucks. Rodotrem was considered the trucks that carried loads over 43 thousand kilos, Bitrem the trucks that carried loads between 33 thousand and 43 thousand kilos, and Others the trucks that carried loads with weight under 33 thousand kilos, considering weight of scale. These classifications were made considering resolutions 210/06 [9] that establishes the limits of weight and dimensions for vehicles that transit by land routes [9].

The Bitrem truck (7 axles) was used as the basis for calculating the losses, since during the interviews this was the type that had the most occurrences in BRs evaluated, with 39%. Therefore, based on the questionnaire, the load weight of 38,000 kg was adopted.

### 2.3 Calculation of the Indicators for the Determination of Losses

The calculation of the indicators involved the measurement of the frequency of travel and distance traveled, considering the repetition of trips. To determine the frequency was based on the number of times a passage was traveled. The total distance was calculated by multiplying the distance (Km) by the number of times the section was traveled. The loss per Km was calculated based on the expression:

$$\frac{\sum_{i=1}^{n} \text{Losses}}{\sum_{i=1}^{n} \text{Distance (in km)}}$$

For the calculation of the total loss losses were added per section. And the loss index was calculated according to the formula:

$$\frac{\text{Average Losses (in Kg)}}{\text{Average Weight (departure)}}$$

To compare the loss index of 0.25%, a statistical test was performed based on the mean and standard deviation of the losses, sample size, at 1% significance.

The Z distribution was chosen according to the expressiveness of the sample (>50). The hypotheses of the test were as follows:

$H_O: \mu \geq 0{,}0025$ --→ Null hypothesis (this hypothesis, if it prevails, will indicate that, in fact, the average value of losses is greater than or equal to 0.0025).

$H_a: \mu < 0{,}0025$ --→ Alternative hypothesis (this hypothesis assumes that the mean value is less than 0.0025).

It was verified, by means of a cointegration model, what would be the long-term behavior of the estimated series. Being:

$X_1 =$ Initial weight, in kg, of grain to be transported.
$X_2 =$ Final weight in kg of grain to be transported.

Period analyzed: 2013 to 2016.

The hypothesis that the problem of grain loss will last for a long period is assumed in the model.

The cointegration model is divided into.

**Unitary root test:** The unit root test is formally used to detect the presence or absence of stationarity in the series. The increased Dickey-Fuller and Dickey-Fuller methods are used more frequently in the detection of stationarity in time series.

The null hypothesis, according to the three methods, assumes that there is a unit root in the series, while the alternative assumes that there is no unit root and, consequently, the series is stationary, in the second hypothesis, and not stationary in the first.

**Table 1. Principal routes of corn grain outflow in BR 163/364 - MT, Brazil**

| Route | Distance (Km) | Highway (BR) |
|---|---|---|
| Sinop-MT to Rondonópolis -MT | 696 | 163/364 |
| Sorriso-MT to Porto de Paranaguá-PR | 2,201 | 163/364 |

*Source: Google Maps*


**Fig. 1. Main route of maize flow in the State of Mato Grosso, BR 163/364, route from Sinop to Rondonópolis, Mato Grosso, Brasil. Source: Google maps 2019**

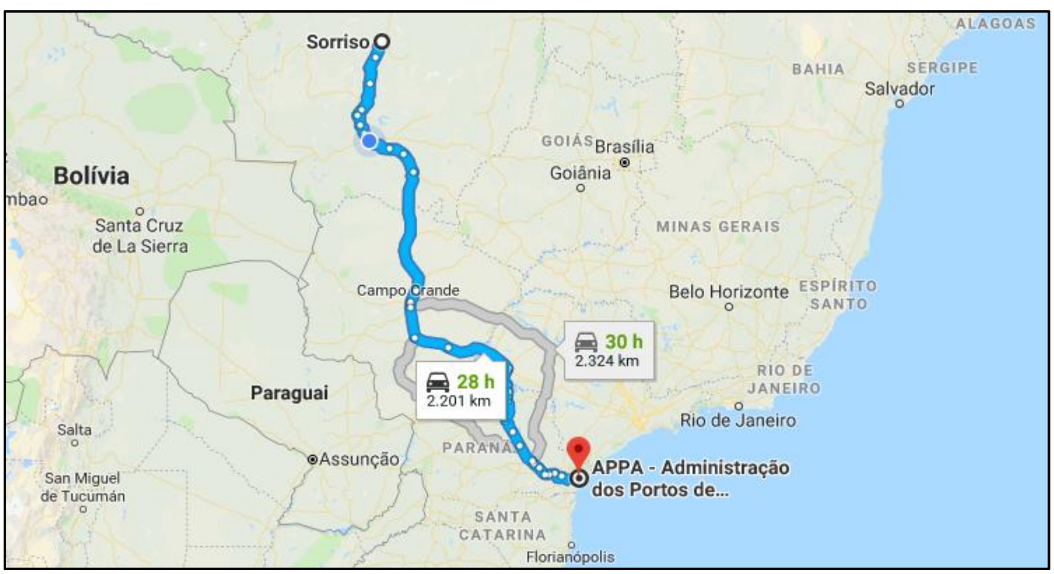


**Fig. 2. Main route of maize flow in the State of Mato Grosso, BR 163/364, route from Sorriso, Mato Grosso, Brasil to the Port of Paranaguá, Paraná, Brasil. Source: Google Maps 2019**

The regression, according to the increased Dickey-Fuller method, is estimated according to equation 1. The regression format is similar to the first order auto regression process or AR (1).

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \varepsilon_t \quad (1)$$

Being $\beta_0$ e $\beta_1$ the regression parameters and $\varepsilon_t$, the white noise.

If $(-1 < \beta_0 < 1)$. If $\beta_0 = 1, Y_t$ is a non-stationary series (a random path with an intercept), because if the process starts from some point, the variance of $Y_t$ grows as a function of time to infinity. If the absolute value of the parameter is greater than one $(|\beta_0| > 1)$ , The series is explosive. Consequently, the stationarity hypothesis must be tested to evaluate whether the absolute value of $\beta_0$ is strictly smaller than one. Both tests DFA and PP allow to evaluate the presence of a unit root as null hypothesis, that is, that: $H_0: \beta_0 = 1$ [10].

If the null hypothesis, which assumes the presence of unit root in the series, is not rejected, but when reestimated in its first difference, the test confirms the stationary nature of the model, it is concluded that the series is integrated of order 1 or $I\{1\}$. Conventionally, the original series is labeled random path.

If it is necessary to differentiate the original series twice, that is, to take the first difference from the first difference, before the series is converted to stationary, the original series is $I\{2\}$ or integrated order 2. In general, if a time series has to be differentiated n times, then it will be integrated order n or $I\{n\}$. Buf, if $n = 0$, the time series is stationary without differentiation or $I\{0\}$ [11].

The Dickey-Fuller test for the presence of unit root in the series can be performed with intercept or without intercept, in the same way for the trend. Equations 2,3 and 4 illustrate the regression format for these situations.

$$\Delta Y_t = \theta Y_{t-1} + \varepsilon_t \quad (2)$$
$$\Delta Y_t = \beta_i + \theta Y_{t-1} + \varepsilon_t \quad (3)$$
$$\Delta Y_t = \beta_i + \beta_j t + \theta Y_{t-1} + \varepsilon_t \quad (4)$$

The critical values do not belong to the t student distribution. The statistic used as a basis for comparison with the calculated value follows the distribution $\tau$ (tau).

The main objective of the cointegration tests is to verify if in a group of non-stationary time series there is at least one linear combination that is stationary, that is, if they are cointegrated [10].

The main objective of the cointegration tests is to verify if in a group of non-stationary time series there is at least one linear combination that is stationary, that is, if they are cointegrated.

$$X_T = \beta_0 + \beta_1 P_{st} + \varepsilon_t \quad (5)$$

The residues resulting from this regression will be estimated in their first difference as a function of the same residuals lagged in the first order, as shown in equation 6.

$$\Delta e_t = \rho e_{t-1} + \lambda_1 \Delta e_{t-1} + \lambda_2 \Delta e_{t-2} + \ldots \Delta e_{t-q} + v_t \quad (6)$$

If the calculated value of the statistic τ exceeds, in absolute terms, the critical values, it is concluded that the $\varepsilon_t$ estimated is stationary, which means cointegration between the variables.

Johansen created a model without a constant in which the dependent variable is estimated as a function of it lagged up to the order $t - p$ and the independent variable not lagged.

This model is illustrated in equations 7 and 8, being $Z_t$ a non-stationary series I{1}, $Y_t$ a deterministic and $\varepsilon_t$ a white noise.

$$Z_t = a_1 Z_{t-1} + a_2 Z_{t-2} + a_3 Z_{t-4} + \ldots\ldots a_p Z_{t-p} + bY_t + \varepsilon_t \quad (7)$$
$$\Delta Z_t = aZ_{t-1} + \sum_{i=1}^{p-1} \lambda_i \Delta Z_{t-i} + bY_t + \varepsilon_t \quad (8)$$

The cointegration is tested by the eigenvalues, generated by the likelihood ratio. Statistical tests, conventionally known as $\lambda_{traço}$ e $\lambda_{max}$ , are compared with critical values [10].

$$\lambda_{traço}(r) = -T \sum_{i=1+r}^{k} \ln(1 - \hat{\lambda}_i) \quad (9)$$
$$\lambda_{max}(r, r+1) = -T * \quad (10)$$

$\hat{\lambda}_i$ = i-th highest eigenvalue (or characteristic root)
$T$ = number of usable observations
$k$ = number of endogenous variables
$r$ = rank of cointegration

## 2.4 Statistical Analysis

The first statistic tests the null hypothesis that the number of distinct cointegration vectors is less than r against the generic alternative. The second statistic tests the null hypothesis that the number of cointegration vectors is equal to r against the alternative of r+1 vectors of cointegration. If the estimated value of the characteristic root (eigenvalue) is close to zero, then $\lambda_{\max}$ it will be inexpressive [12].

The null hypothesis assumes that there is no cointegration relation between the variables, while the alternative hypothesis assumes that there is at least one cointegration relation between the variables. The test is repeated until rejection of the null hypothesis is obtained.

$$H_0: r = 0$$
$$H_A: r > 0$$

The error term in the cointegration equation is treated as "equilibrium error", according to Gujarati [11]. This error term can be used as a link of the behavior, applying in the variables selected for the search, in the short term with its value in the long term. The error correction mechanism is the corrective component of imbalances in the short term. The equation of this mechanism is expressed in 11.

$$\Delta X_{1t} = \alpha_0 + \alpha_1 \Delta X_{2t} + \alpha_2 e_{t-1} + u_t \qquad (11)$$

If the error coefficient lagged in the first order ($\boldsymbol{\alpha_2}$) is statistically significant, this parameter informs in what proportion the imbalance in the data in one period is corrected in the following period.

The obtained data were submitted to descriptive statistics from where a breakdown frequency analysis was obtained. The statistical program used to perform the frequency analysis was the IBM SPSS Statistics Version 22.

## 3. RESULTS AND DISCUSSION

For the study of corn grain losses in road transport, 39,642 data were analyzed for routs, of which 24,902,808.50 km were routed, an average of 628.19 km of distance per route. The amount of corn grain transported was 1,852,437,042 kg. The total losses were 1,808,951 kg, averaging 45.63 kg of loss per trip. The loss per km was on average of 0.072 kg.

In the first step, the calculation of the indicatives involved the measurement of travel frequency, distance traveled and total loss, considering the repetition of trips in the transportation of corn grains (Fig. 3).

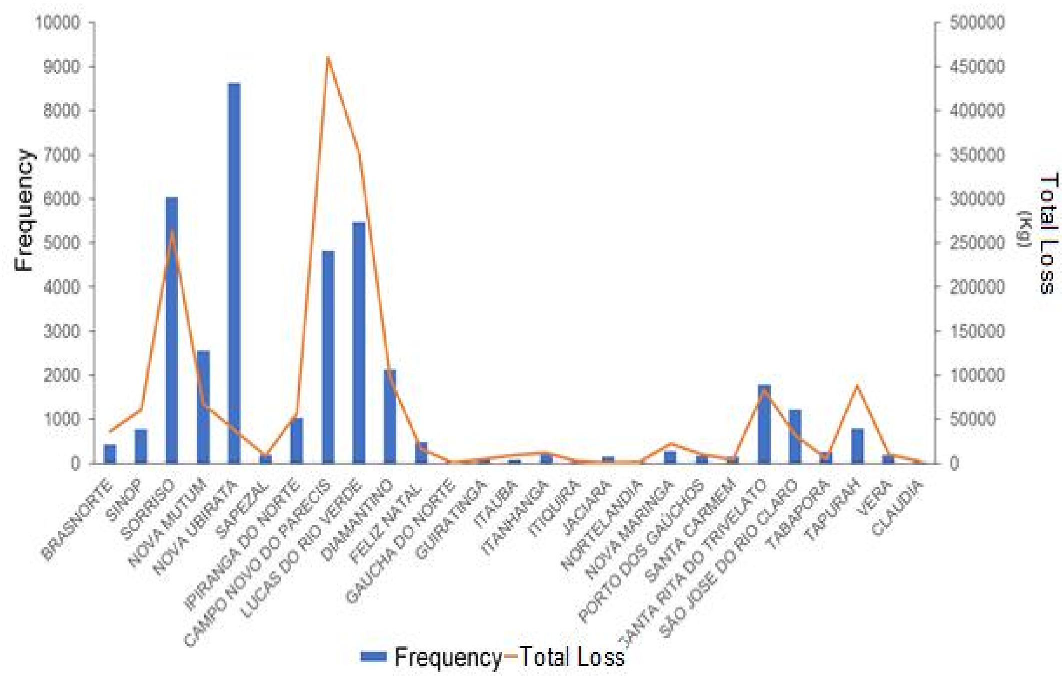


**Fig. 3. Frequency of road transport and their respective total losses of corn grains from the municipalities of origin to the final destination, Rondonópolis, Mato Grosso, Brasil, during the period from 2013 to 2016**

During the research it was possible to identify, through the romaneios, the frequency of the trips as well as the total loss in the transportation of corn grains (Fig. 3). It was verified that the greatest losses occurred in the section between the municipalities of Campo Novo do Parecis and Rondonópolis and Lucas do Rio Verde to Rondonópolis, this fact can be explained due to the bad state of conservation of the section during the evaluations. The authorsneves [13] explain that due to poor road conditions, where the irregularities, and the large number of holes found cause the truck to shake, as a consequence of this trepidation the oscillation and displacement of these grains to the periphery occurs, and if the body does not is in good condition and well fenced, these grains fall down the highway. It should be considered that although producers and drivers are aware of this loss, they are not careful to take preventive measures, because they believe that they are insignificant and do not cause them any loss, but in the end there is a lot of waste [14]. According to [15] with only 20% of road pavements and 1.7 million km of road surface, poor rural road conditions in Brazil create substantial bottlenecks due to intensive use during the soybean and corn harvest. According to Danao et al. [16], Brazilian law states that trailers may have a maximum weight of 45 or 57 tonnes (based on the total length of the trailer, [9], however the overload during transport of grain farm, for storage is common. The combined effects of poor road conditions and road maintenance, truck vibrations and overloads, and lack of maintenance of trailers on grains lost during transport were studied [17,18].

The transport of corn grains between Nova Ubiratã and Rondonópolis presented the highest frequency of travel (8629 trips), however the losses were 37,710 kg of grains, or approximately 628 bags of corn (60 kg). In this way it is considered a low volume lost, since it can be said that the loss was only 4.37 kg per trip. This stretch has a few tolls, which explains the low volume lost, since the highway had good or excellent state of conservation. According to the authors [19,20,21,22], the BR-163 concession has a direct impact. Understanding that the concession represents first the improvements, being in the pavement, signaling and geometry of the roads, secondly the consideration to the concessionaires will be given by toll collection of the public service user.

In the second stage, the Hypothesis Test was performed to compare with the current loss index, which is 0.25% [7]. The test indicated that one should reject the null hypothesis, which states that the mean value of the losses is greater than or equal to 0.25%, and accept the alternative hypothesis, which states that the average value of losses is lower than the value of 0.25%. Later, the extreme values of losses represented by the lower and upper limits were calculated using the confidence interval method (Table 2).

Thus, the percentage loss index for maize (0.1025%) was determined. This percentage is lower than the adopted one that is of 0.25%, nevertheless, represent considerable losses for the economy. According to [23], about 0.25% of the grains that are carried along the route. By contract, such loss, when greater than 0.2%, is banked by the carrier himself. But the economic impact is felt throughout the production chain until the final consumer, who ends up paying more expensive for the product.

In the third step a cointegration model was applied, whose objective was to verify the behavior of the estimated series, in the case grain losses, for a long period (Table 3). This model uses the same statistical assumptions presented in the state distribution model, with the difference that the distribution occurs at the national level.

The variables of the estimation are as follows:

$Q_1 =$ Initial weight, in kg, of the product transported.
$Q_2 =$ Final weight, in kg, of the product transported.

The result of the applied statistical model showed a stable relationship of the cointegrated variables studied. It was verified through the models that grain losses can last for long periods if there is no effective intervention of the sectors involved, both privately and publicly.

With the application of the indexes, it is possible to calculate the amount lost in kilograms of grain transported by a bitrem truck with a capacity of 38 t, in addition to assessing this loss (Table 4).

In the corn grain road transport, 0.1025% of the transported cargo is lost, for example, a load of 38,000 kg is equivalent to say that 38.95 kg is what can be lost. When using this index of 0.1025% to evaluate the losses, the route from Sinop-MT to Rondonópolis-MT and Sorriso-MT to the port of Paranaguá-PR was used, with total losses of R$ 10.85 and R$ 11.03, respectively. The common tolerance between the carriers is 0.25% of the total load, this value that if extrapolated is the responsibility of the drivers.

It is possible to perceive how much is lost when comparing the difference between the percentage indices of losses found and the index of 0.25% practiced today (Table 5). It has been found that when transporting 38,000 kg of maize grains, for example, it is allowed to lose up to 95 kg of that amount, using the current index which is 0.25%. However, using the 0.1025% index indicated in this study, the acceptable loss would be only 39 kg approximately, a value well below that practiced.

What is lost holds great importance in the value of the product to the consumer, since the final price is influenced by the amount of product available. Thus, with demand continuing and with a percentage of grain being lost, the final price of the industrialized product will be more expensive at the consumer's table [24]. In addition to economic aspects, grain losses have a high social significance, as they result in a decrease in the supply of food to the population.

**Table 2. Indices of losses of corn grains, upper and lower limits in BR 163/364 - MT, Brazil**

| | **Confidence interval (%)** | |
|---|---|---|
| | **Inferior limit** | **Upper limit*** |
| Corn | 0.0991 | 0.1025 |

*The upper limit was adopted as the indicated index for the calculation of the losses*

**Table 3. Cointegration model of the estimated series for grain loss over a long period**

| **Product** | **Auto value** | **Trace statistic** | **Critical value** |
|---|---|---|---|
| Corn | 0.16 | 14,247 | 15.49 |
| | 0.13 | 6,317 | 3.84 |

**Table 4. Quantitative losses in road transport of corn grains indicated by means of a percentage index**

| **Route** | **Distance (Km)** | **Truck bitrem (kg)** | **Loss index (%)** | **Losses (Kg)** | **Price R$/60Kg** | **Losses (Kg/Km)** | **Losses (R$/km)** | **Losses Totals* (R$)** |
|---|---|---|---|---|---|---|---|---|
| **Corn** | | | | | | | | |
| Sinop-MT to Rondonópoli s -MT | 696 | 38,000 | 0.1025 | 38.95 | 16.71 | 0.056 | 0.015596 | 10.85 |
| Sorriso-MT to Porto de Paranaguá-PR | 2.201 | 38,000 | 0.1025 | 38.95 | 16.71 | 0.018 | 0.005013 | 11.03 |

**Total Losses= Losses (R$/Km) x Distance*

**Table 5. Comparison between the percentages of losses found for road grain transport and the index practiced**

| **Product/Route** | **Distance (Km)** | **Truck Bitrem(Kg)** | **Loss rate used** | **Loss index indicated** |
|---|---|---|---|---|
| **Corn** | | | **0.25%*** | **0.1025%*** |
| Sinop-MT to Rondonópolis -MT | 696 | 38,000 | 95 | 38.95 |
| Sorriso-MT to Porto de Paranaguá-PR | 2,201 | 38,000 | 95 | 38.95 |

**Values expressed in Kg*

## 4. CONCLUSION

Based on the data obtained in the present study, it can be stated that it is possible to adopt, by the carriers, percentage loss indexes lower than 0.25% in the contracts. It is recommended to adopt the percentage rates of grain loss in road transport of 0.10% for maize.

## CONSENT

It is not applicable.

## ETHICAL APPROVAL

It is not applicable.

## COMPETING INTERESTS

We declare that no competing interests exist.

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