# Testing Stochastic Models for Simulating the Seeds Separation Process on the Sieves of a Cleaning System, and a Comparison with Experimental Data

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## Summary

A common method of analyzing experimental data is to determine the distributional model which best describes the process under study. In this paper, theoretical statistical models discussed by Tarcolea et al. (2008) are corroborated with data for the cleaning system of a combine harvester, data obtained experimentally in laboratory conditions.

The purpose of this paper is to illustrate how some of the continuous distributions can be used for describing the variation separation intensity of seeds on sieve length. The Pearson coefficients show that some curves are far from the normal distribution, and better fits can be obtained with other distributions which can describe more adequately different degrees of skewness and peakedness of the curves. The considered probability laws are: normal, gamma, Weibull and beta distributions. The best results were obtained with gamma and beta distributions, since, for example, the values of the correlation coefficient $R^2$ are in the most of the corresponding cases close to 1.

## Key words

combine harvester; cleaning system; seed separation; normal, Weibull, gamma and beta distributions

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## Introduction

Since the cleaning system is one of the most important equipment of a combine harvester, its performance influence the performance of the entire combine. In the cleaning system, the seeds are separated from the pile of material resulted from threshing apparatus and walkers. The separation process takes place on the sieves of the cleaning system thanks to the oscillation movement of the sieves and of the ascending air flow which permeates the layer of material (Zaika, 1975).

It is also important to make a correct evaluation of the percentage of seed losses (the usually imposed condition is that the loss should be smaller than 1.5%), value relevant for the design of the cleaning system and for its efficient use under real work conditions (Voicu, 1996).

In fact, the particles movement through the material layer is random, due to the material heterogeneity and to the irregularity of the seeds, which have different dimension and form, smooth or raw surfaces, different degrees of humidity or density and so on.

Since the seeds separation process has a random nature, numerous surveys which are concerned with the modelling of this process are based on stochastic theory (Song, 1990; Wang, 1994). Hence, the seed losses in the cleaning systems can be anticipated by different stochastic models, motivated theoretically as well as empirically, [Gregory, 1987; Schreiber, 2003; Voicu, 2004, 2005, 2006, 2007).

The natural variability, the abundance of factors that influences the separation process and their random character are comprised in the mean values of the constant coefficients in the proposed models.

One of the disadvantages of using these relations is the fact that one has to choose the best coefficient values, which depend on the real work conditions, on the material properties, on the geometry of the cleaning system and its functional parameters (Voicu, 2004, 2005). In order to solve this problem, at least partially, the mathematical model of the logistic function with two parameters was developed in (Voicu, 2006), model that describes the most important design and work parameters of the cleaning system. Multiple linear regression functions were proposed for the logistic coefficients, and the fit with the experimental data was good ($R^2 \geq 0.911$) (Voicu, 2006).

In a similar manner, a mathematical model was proposed by Voicu et al. (2007), model which accounts for seven of the main design, work and material characteristics parameters of the cleaning system. A good concordance of the model with the experimental data was obtained ($R^2 \geq 0.837$).

After analyzing the profile of the curves describing the intensity of separation on the sieve length, the curves for most of the experimental samples were shown to be asymmetric (Voicu, 1996). Hence the modelling by gamma or beta distribution – truncated on a finite interval – is more adequate (Tarcolea, 2008).

In this paper following issues will be pursued: a) testing the adequateness of the proposed distribution laws for experimental data; b) the comparative analysis of the specified distribution laws for the separation intensity variation of seeds on sieve length; c) identification of the most adequate distribution law and d) forecasting the seed losses on the sieve by using the proposed distribution law.

## Material and methods

The separation process of seeds on sieve length, executed by the cleaning system of the harvesting combines, can be evaluated by separation intensity, which is defined as the separated seed quantity on length unit, in a section x from the sieve head, in percentage, in relation with the whole quantity separated by sieve (Baumgarten, 1987).

The distribution analysis of experimental data points for the separation intensity on upper sieve length of the cereal combine harvester's cleaning system indicate that curve profiles have a bell shape with a certain asymmetry degree. This profile can be described more or less adequately by means of different equation forms known in the mathematical models literature (Schreiber, 2003; Voicu, 2004, 2005).

Two important distribution characteristics are captured by central moments of higher order, namely skewness and kurtosis (Heike, 2000; John, 1990).

The skewness or the coefficient of asymmetry of a sample is given by:

$$g_3 = \frac{\sum_{i=1}^{I} f_i \left(\overline{x_i} - \overline{x}\right)^3}{\left[\sum_{i=1}^{I} f_i \left(\overline{x_i} - \overline{x}\right)^2\right]^{3/2}} \qquad (1)$$

K. Pearson proposed a measure to describe the degree of skewness, called coefficient of skewness:

$$g_3^* = \frac{3\left(\text{mean} - \text{median}\right)}{\text{standard deviation}} \qquad (2)$$

For a distribution symmetric about the line $x = \overline{x}$, the odd central moments are all zero, and so the skewness is zero.

If one or more observations are extremely large, the mean of the distribution becomes larger than the median and the distribution is called positively skewed. If one or more observations are extremely small, the mean of the distribution becomes smaller than the median and the distribution is called negatively skewed.

Kurtosis measures the peakedness of a distribution. The coefficient of kurtosis of a sample is obtained as:

$$g_4 = \frac{\sum_{i=1}^{I} f_i \left(\overline{x_i} - \overline{x}\right)^4}{\left[\sum_{i=1}^{I} f_i \left(\overline{x_i} - \overline{x}\right)^2\right]^2} \qquad (3)$$

The kurtosis of the standard normal distribution is 3, fact relevant because this distribution is usually used as the reference distribution, (Lipson, 1973; Heike, 2000).

A curve is called a leptokurtic curve ("lepto" means slender) if $g_4 > 3$.

A curve is called a mesokurtic curve ("meso" means intermediate) if $g_4 = 3$.

A curve is called a platykurtic curve ("platy" means flat) if $g_4 < 3$.

Same authors use directly the excess (coefficient of excess): $g_5 = g_4 - 3$.

If the coefficients of skewness and excess of a sample are not equal to zero, the population is not distributed according to a normal distribution. Since this happens often in practice, we also consider the use of other distributions.

In this paper we apply hence following types of distributional functions: normal, gamma, Weibull and beta distributions (Tiku, 1974; Lapin, 1990; Lawless, 2002):

$$f_1(x) = \frac{1}{\sigma\sqrt{2\cdot\pi}} \exp\left(-\frac{(M-x)^2}{2\cdot\sigma^2}\right) \qquad (4)$$

$$f_2(x) = c\cdot x^a \cdot e^{-b\,x} \qquad (5)$$

$$f_3(x) = m\cdot(x-0.075)^2\cdot e^{-\frac{(x-0.075)^3}{n}} \qquad (6)$$

$$f_3^*(x) = m\cdot(x-0.075)\cdot e^{-\frac{(x-0.075)^2}{n}} \qquad (6^*)$$

$$f_4(x) = k\cdot(x-0.075)^{\alpha}\cdot(1.275-x)^{\beta} \qquad (7)$$

The experimental stand sieve has a length of 1.2 m. The seeds were collected under the sieve in eight compartments, each with a length of 0.15 m. The seed losses were collected in an additional compartment, so the last interval mean was at 1.275 m distance from the sieve head. Because the normal, Weibull and gamma distributions have unbounded ranges, while the sieve length is bounded, models truncated on the bounded interval [0.075; 1.275] were used in this paper. In the case of beta distribution,

**Table 1.** Separated seeds percentage (separation intensity) on sieve length

| No. sample | Sieve length from which seeds are collected $x$ (m) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.075 | 0.225 | 0.375 | 0.525 | 0.675 | 0.825 | 0.975 | 1.125 | 1.275 |
| 1 | $f = 280$ osc/min; $q = 0.15$ kg/dm·s; $v_a = 8$ m/s; $D_j = 12.5$ mm; $pp/s = 0.24$ | | | | | | | | |
| | 2,7 | 9,6 | 33,5 | 36,2 | 13,2 | 3,6 | 0,8 | 0,2 | 0,2 |
| 2 | $f = 280$ osc/min; $q = 0.10$ kg/ dm·s; $v_a = 8$ m/s; $D_j = 11$ mm; $pp/s = 0.25$ | | | | | | | | |
| | 2,5 | 8,3 | 25,3 | 26,2 | 20,8 | 10,8 | 4,2 | 0,5 | 1,4 |
| 3 | $f = 280$ osc/min; $q = 0.15$ kg/ dm·s; $v_a = 8$ m/s; $D_j = 11$ mm; $pp/s = 0.27$ | | | | | | | | |
| | 1,7 | 6,2 | 23 | 27,1 | 22 | 12,6 | 5,6 | 1 | 0,8 |
| 4 | $f = 280$ osc/min; $q = 0.20$ kg/ dm·s; $v_a = 10$ m/s; $D_j = 11$ mm; $pp/s = 0.27$ | | | | | | | | |
| | 4,2 | 12 | 21,6 | 19,9 | 19,5 | 14,5 | 7,4 | 0,7 | 0,2 |
| 5 | $f = 190$ osc/min; $q = 0.10$ kg/ dm·s; $v_a = 8$ m/s; $D_j = 11$ mm; $pp/s = 0.25$ | | | | | | | | |
| | 17 | 42,8 | 30,5 | 7,1 | 1,7 | 0,45 | 0,25 | 0,1 | 0,1 |
| 6 | $f = 240$ osc/min; $q = 0.10$ kg/ dm·s; $v_a = 8$ m/s; $D_j = 11$ mm; $pp/s = 0.25$ | | | | | | | | |
| | 8,3 | 23,5 | 41,8 | 20,9 | 4,2 | 0,8 | 0,35 | 0,1 | 0,05 |
| 7 | $f = 335$ osc/min; $q = 0.20$ kg/ dm·s; $v_a = 10$ m/s; $D_j = 11$ mm; $pp/s = 0.252$ | | | | | | | | |
| | 0,2 | 0,8 | 3,1 | 13,9 | 22,6 | 20,8 | 16,8 | 15,8 | 6 |
| 8 | $f = 280$ osc/min; $q = 0,15$ kg/dm·s; $v_a = 6,2$ m/s; $D_j = 12,5$ mm; $pp/s = 0,25$ | | | | | | | | |
| | 3,3 | 10 | 32,7 | 35,5 | 13,1 | 3,8 | 0,7 | 0,2 | 0,7 |
| 9 | $f = 280$ osc/min; $q = 0,15$ kg/dm·s; $v_a = 10$ m/s; $D_j = 12,5$ mm; $pp/s = 0,25$ | | | | | | | | |
| | 2 | 7,7 | 33,9 | 36,5 | 14,5 | 3,6 | 1 | 0,3 | 0,5 |
| 10 | $f = 280$ osc/min; $q = 0, 50$ kg/dm·s; $v_a = 5$ m/s; $D_j = 9$ mm; $pp/s = 0,27$ | | | | | | | | |
| | 6,7 | 18 | 28,7 | 21,3 | 14 | 5,2 | 3,4 | 2,4 | 0,3 |
| 11 | $f = 280$ osc/min; $q = 0,1$ kg/dm·s; $v_a = 5$ m/s; $D_j = 9$ mm; $pp/s = 0,26$ | | | | | | | | |
| | 4,8 | 11,7 | 23,2 | 18,7 | 17,3 | 11,2 | 10,3 | 2,5 | 0,3 |
| 12 | $f = 280$ osc/min; $q = 0,15$ kg/dm·s; $v_a = 5$ m/s; $D_j = 9$ mm; $pp/s = 0,27$ | | | | | | | | |
| | 4,5 | 10,9 | 17 | 22,5 | 17,6 | 12,3 | 10 | 4,9 | 0,3 |
| 13 | $f = 335$ osc/min; $q = 0,10$ kg/dm·s; $v_a = 8$ m/s; $D_j = 11$ mm; $pp/s = 0,25$ | | | | | | | | |
| | 0,9 | 2,7 | 10,5 | 15,6 | 19,8 | 20,9 | 20 | 7,1 | 2,5 |

which is defined on the canonical [0;1] interval, we provided a model adapted for our case.

The experiments were conducted with wheat pile material on laboratory stand under simulation of different

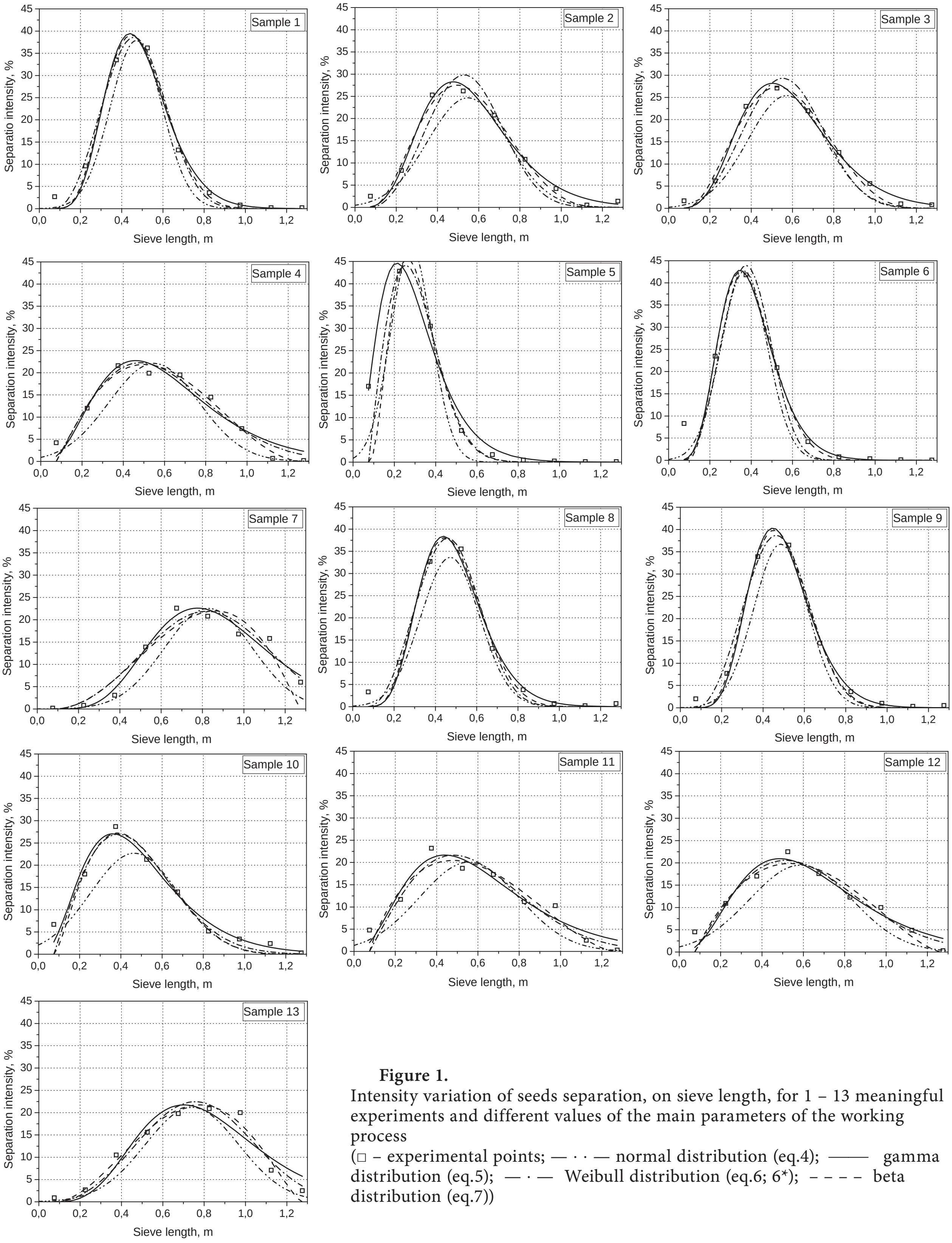

**Figure 1.**
Intensity variation of seeds separation, on sieve length, for 1 – 13 meaningful experiments and different values of the main parameters of the working process
(□ – experimental points; — · · — normal distribution (eq.4); ——— gamma distribution (eq.5); — · — Weibull distribution (eq.6; 6*); – – – – beta distribution (eq.7))

work conditions. The parameters of interest, which were modified during experiments in order to determine their influence on the separation process, are: specific supply flow *q*; air flow velocity at the ventilator exit $v_a$; blinds opening $D_j$; straw parts per seeds ratio *pp/s* and oscillation frequency *f*. The parameter values and experimental results are presented in Table 1.

## Results and discussions

For each experimental sample from table 1, the seed separation intensity on the sieve length was graphically represented; the regression curves for the proposed models (eq. 4–7) are provided in the Figure 1. Used software packages were Microcal Origin, MathCAD and Microsoft Excel.

In Table 2 and Table 3, the regression coefficient values and the correlation coefficients $\chi^2$ and $R^2$ are presented for the analyzed functions.

In the case of the normal distribution, we used Shepard's correction for the variance, denoted $(\sigma^*)^2$. The coefficients $C_1$, $c^*$, $m^*$, $k^*$ (Tables 2-3) are obtained under necessary normality condition, i.e. the area under the curve of density function is equal unity.

In Table 4, the values of skewness, kurtosis and excess are presented, as estimated by the equations (a, b, c) for $g_3$, $g_4$, $g_5$.

In most cases, the observed values are large and the distributions are positively skewed. On the other hand, there are more samples which have a small variance and hence present a big degree of peakedness, compared to the normal distribution. An explication for this variability of the samples is the diversity of work conditions. In other words, one must choose the adequate model for each experiment.

**Table 2.** The coefficients values M, $\sigma^*$, $C_1$, a, b, c, $c^*$, obtained through testing relations (4) and (5) with experimental data and correlation coefficients values $\chi^2$ and $R^2$

| No. Sample | Normal distribution (4) | | | | Gamma distribution (5) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M | $\sigma^*$ | $R^2$ | $C_1$ | a | b | c | $c^*$ | $\chi^2$ | $R^2$ |
| 1 | 0.471 | 0.126 | 0.979 | 6.654 | 9.127 | 20.736 | $6.50\cdot10^{8}$ | $4.47\cdot10^{7}$ | 3.95 | 0.985 |
| 2 | 0.547 | 0.194 | 0.950 | 6.653 | 5.335 | 11.218 | $3.09\cdot10^{5}$ | $2.10\cdot10^{4}$ | 2.08 | 0.986 |
| 3 | 0.572 | 0.188 | 0.946 | 6.661 | 5.803 | 11.525 | $5.00\cdot10^{5}$ | $3.37\cdot10^{4}$ | 1.05 | 0.993 |
| 4 | 0.549 | 0.217 | 0.900 | 6.633 | 3.0.59 | 6.645 | $5.20\cdot10^{3}$ | $3.49\cdot10^{2}$ | 6.81 | 0.927 |
| 5 | 0.281 | 0.099 | 0.944 | 6.658 | 2.578 | 12.131 | $3.19\cdot10^{4}$ | $2.14\cdot10^{3}$ | 4.95 | 0.985 |
| 6 | 0.366 | 0.112 | 0.965 | 6.665 | 7.374 | 21.325 | $1.72\cdot10^{8}$ | $1.24\cdot10^{7}$ | 11.27 | 0.961 |
| 7 | 0.829 | 0.213 | 0.864 | 6.624 | 7.562 | 9.739 | $2.94\cdot10^{5}$ | $2.03\cdot10^{4}$ | 3.71 | 0.963 |
| 8 | 0.472 | 0.142 | 0.993 | 6.665 | 8.756 | 19.951 | $3.30\cdot10^{8}$ | $2.30\cdot10^{7}$ | 4.89 | 0.981 |
| 9 | 0.485 | 0.130 | 0.980 | 6.666 | 9.814 | 21.951 | $1.99\cdot10^{9}$ | $1.37\cdot10^{8}$ | 1.69 | 0.994 |
| 10 | 0.466 | 0.213 | 0.916 | 6.582 | 2.929 | 8.082 | $9.88\cdot10^{3}$ | $6.78\cdot10^{2}$ | 4.86 | 0.962 |
| 11 | 0.557 | 0.240 | 0.835 | 6.603 | 2.557 | 5.823 | $2.29\cdot10^{3}$ | $1.55\cdot10^{2}$ | 6.49 | 0.918 |
| 12 | 0.587 | 0.247 | 0.925 | 6.608 | 2.927 | 6.0.16 | $3.22\cdot10^{3}$ | $2.21\cdot10^{2}$ | 4.98 | 0.927 |
| 13 | 0.741 | 0.226 | 0.908 | 6.644 | 6.048 | 8.624 | $7.87\cdot10^{4}$ | $5.44\cdot10^{3}$ | 9.51 | 0.894 |

**Table 3.** The coefficients values m, $m^*$, n, k, $k^*$, $\alpha$, $\beta$, obtained through testing relations (6), (6*) and (7) with experimental data and correlation coefficients values $\chi^2$ and $R^2$

| No. Sample | Weibull distribution (6; 6*) | | | | | Beta distribution (7) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | m | $m^*$ | n | $\chi^2$ | $R^2$ | k | $k^*$ | $\alpha$ | $\beta$ | $\chi^2$ | $R^2$ |
| 1 | 510.2 | 35.294 | 0.085 | 2.11 | 0.991 | 11801.1 | 824.3 | 4.052 | 9.019 | 2.76 | 0.990 |
| 2 | 281.2 | 21.277 | 0.141 | 9.04 | 0.926 | 487.8 | 34.0 | 2.169 | 3.999 | 2.63 | 0.982 |
| 3 | 249.3 | 18.293 | 0.164 | 6.00 | 0.952 | 516.0 | 35.6 | 2.306 | 3.807 | 1.91 | 0.987 |
| 4* | 89.6 | 6.035 | 0.336 | 5.50 | 0.932 | 98.2 | 6.7 | 1.140 | 2.061 | 4.49 | 0.952 |
| 5* | 406.3 | 31.250 | 0.064 | 41.50 | 0.854 | 2340.4 | 190.6 | 2.449 | 13.225 | 48.40 | 0.854 |
| 6 | 953.2 | 75.000 | 0.040 | 13.70 | 0.944 | 7550.4 | 557.3 | 3.332 | 11.238 | 11.54 | 0.960 |
| 7 | 76.9 | 5.156 | 0.620 | 5.40 | 0.937 | 100.7 | 8.3 | 2.162 | 1.250 | 14.64 | 0.854 |
| 8 | 499.8 | 35.294 | 0.085 | 2.50 | 0.988 | 9183.0 | 648.6 | 3.890 | 8.687 | 3.65 | 0.986 |
| 9 | 498.1 | 34.081 | 0.088 | 2.60 | 0.989 | 16868.4 | 1176.0 | 4.327 | 9.379 | 1.23 | 0.996 |
| 10* | 142.3 | 10.211 | 0.196 | 8.20 | 0.927 | 258.0 | 19.1 | 1.494 | 4.276 | 10.05 | 0.922 |
| 11* | 87.8 | 6.139 | 0.330 | 7.90 | 0.883 | 68.4 | 4.7 | 0.892 | 1.749 | 9.18 | 0.884 |
| 12* | 77.3 | 5.334 | 0.384 | 4.80 | 0.918 | 70.5 | 4.9 | 1.004 | 1.617 | 6.13 | 0.910 |
| 13 | 94.2 | 6.486 | 0.475 | 4.12 | 0.946 | 116.0 | 8.0 | 1.978 | 1.398 | 3.31 | 0.963 |

**Table 4.** The values of skewness, kurtosis and excess

| No. Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skewness, $g_3$ | 1.011 | 0.780 | 0.593 | 0.145 | 4.013 | 1.270 | –0.027 | 0.216 | 0.080 | 0.980 | 0.157 | 0.080 | –0.007 |
| Kurtosis, $g_4$ | 4.424 | 3.537 | 3.159 | 2.332 | 6.919 | 4.346 | 2.379 | 5.407 | 5.403 | 3.411 | 2.333 | 2.359 | 2.511 |
| Excess, $g_5$ | 1.424 | 0.537 | 0.159 | –0.686 | 3.919 | 1.346 | –0.621 | 2.407 | 2.403 | 0.411 | –0.667 | –0.641 | –0.489 |

**Table 5.** The correlation coefficient values $R^2$ and qualitative appreciation of the position of regression curves in comparison with observed data points

| No. Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Normal distribution | 0.979 | 0.950 | 0.946 | 0.900 | 0.944 | 0.965 | 0.864 | 0.993 | 0.980 | 0.916 | 0.835 | 0.925 | 0.908 |
| Gamma distribution | 0.985 | 0.986 | 0.993 | 0.927 | 0.985 | 0.961 | 0.963 | 0.981 | 0.994 | 0.962 | 0.918 | 0.927 | 0.894 |
| Weibull distribution | 0.991 | 0.926 | 0.952 | 0.932 | 0.854 | 0.944 | 0.937 | 0.988 | 0.989 | 0.927 | 0.883 | 0.918 | 0.946 |
| Beta distribution | 0.990 | 0.982 | 0.987 | 0.952 | 0.854 | 0.960 | 0.854 | 0.986 | 0.996 | 0.922 | 0.884 | 0.910 | 0.963 |
| Normal distribution | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Gamma distribution | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | – |
| Weibull distribution | + | – | – | + | + | + | ++ | + | + | ++ | ++ | + | ++ |
| Beta distribution | ++ | ++ | ++ | ++ | – | ++ | + | ++ | ++ | ++ | ++ | ++ | + |

++ curves lie very close for all experimental points; + curves lie close for all experimental points; – curves lie away from the experimental points

**Table 6.** Experimental data and predicted values (eq.4-7) of seeds losses

| No. Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data | 0.20 | 1.40 | 0.80 | 0.20 | 0.10 | 0.05 | 6.00 | 0.70 | 0.50 | 0.30 | 0.30 | 0.30 | 2.50 |
| Normal | $1.0\cdot10^{-5}$ | 0.14 | 0.16 | 0.36 | 0.00 | $6\cdot10^{-10}$ | 6.50 | $2.1\cdot10^{-4}$ | $4.2\cdot10^{-5}$ | 0.10 | 0.77 | 1.20 | 3.60 |
| Gamma | 0.06 | 1.20 | 1.50 | 3.20 | 0.03 | $6.7\cdot10^{-3}$ | 10.20 | 0.08 | 0.05 | 1.10 | 3.50 | 4.20 | 7.90 |
| Weibull | $1.2\cdot10^{-4}$ | 0.03 | 0.08 | 2.40 | $3.3\cdot10^{-6}$ | 0.27 | 9.90 | $1.2\cdot10^{-4}$ | $1.9\cdot10^{-4}$ | 0.30 | 2.30 | 3.40 | 6.30 |
| Beta | $5.9\cdot10^{-5}$ | 0.06 | 0.10 | 0.72 | $2.9\cdot10^{-9}$ | $4.6\cdot10^{-7}$ | 5.00 | $8.9\cdot10^{-5}$ | $4.2\cdot10^{-5}$ | 0.02 | 1.00 | 1.40 | 4.20 |

In table 5, the correlation coefficient values $R^2$ are given for each experimental sample and each chosen distribution, as well as the qualitative appreciation of the positions of the regression curves in comparison with experimental data.

From the analysis of values in Table 5, it results that the gamma and beta distributions have the correlation coefficients larger than other distributions in most cases ($R^2 \geq 0.918$ for gamma and $R^2 \geq 0.952$ for beta).

Similarly, the graphs of gamma and beta distributions are much closer to experimental data for many cases.

The seed losses were predicted for different sieve lengths, the last collected interval has the mean at 1.125 m from the sieve head. The computations were carried out in MathCAD, based on the integrals of the obtained distribution functions, and the results are presented in Table 6. For these predictions, the gamma distribution gives the best results; perhaps the tail of curves is better estimated with unbounded distributions.

## Conclusions

Based on experimental data analysis regarding material separation on cleaning system sieves of cereal combine harvesters, it is found that the intensity variation of the separation process along the sieve is best described by gamma and beta distributions.

These functions have a good fit to experimental data, as shown by the correlation coefficients: $R^2 \geq 0.918$ for the gamma distribution and $R^2 \geq 0.952$ for the beta distribution, for most of the analyzed samples in the survey.

Also, the seed losses estimated by distribution function integrals, exhibit the best fit for experimental results for the Euler functions.

These data and results are useful both in design activity and efficient use of the separation systems of classic combine harvesters, adding to the field data bases.

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