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UNIFORMITY OF AGRICULTURAL GRIND'S GRAIN SIZE DISTRIBUTION

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A b s t r a c t. According to investigations made on barley grinds it was stated that the most simple parameter for determining the homogeneity of grits is the Coefficients of Variation (C.V.) and the exponent n of the Rosin-Rammler's equation. Both of that can be considered as an appropriate physical property of agricultural materials, which mainly depend on the sort and condition of feed grain, machine parameters, etc., showing how the material is desintegrated.

K e y w o r d s: grain size distribution, barley grain, barley grinds

INTRODUCTION

The uniformity of the ground agricultural products is a white spot in the feed milling industry and feeding. Even the requirements are not at all defined. The goal of this paper is the summarizing of the most important research results concerning on the homogeneity of feed grain size distributions, since from the experiences gained up to now, one might come to the conclusion, that the uniformity of ground agricultural materials (like grits) is an appropriate physical property of feeds. If a grind of predetermined quality should be produced for a given feeding purpose, it is not enough to give the particle mean size or the average specific surface area, but the requirements on grain homogeneity must be disclosed numerically, too.

MOST IMPORTANT CHARACTERISTIC PARAMETERS OF GRAIN SIZE DISTRIBUTIONS

ASAE Uniformity Index (U.I.)

The American Society of Agricultural Engineers prepared its recommendations (R 246.1) for the determination of agricultural grinds' fineness early in this century [2], that was adopted also by stock breeders. In this system [14] the uniformity of grits is given by three numbers:

$$U.I. = A : B : C \qquad (1)$$

that are to be calculated from the relevant data of a sieve analysis. The more bigger the first number A is, the coarser is the grind. The more bigger the third number C is, the more finer shall be the grit.

ASAE Recommendation S 319.1 (1968)

In this system [3] on Pfost and Headley's proposal the uniformity of grain size distribution is characterized by the geometric (or logarithmic) standard deviation (s_{gw}) of the mass (weight) distribution according to the particle size's logarithm. It is a dimensionless number this way. Pfost and Headley [15] determined in their detailed investigations - within a wide range of peripheral speed v=28.5 – 83.4 m/s, actual values of s_{gw} numerically: oats=1.7-2.3; sorghum grain=1.5-2.5; and corn=1.6-2.3.

Log-normal distribution

There are to be found two parameters in the Kolmogorov-Rényi's log-normal distribution equations [7]. The homogeneity of grain sizes could be described by the parameter b, which is as well a standard deviation and its reciprocal value $m=l/b$ is the directional tangent of the grain size distribution function's 'straight' line on the logarithmic Gauss net (DIN 66 144).

Parameters of the mathematical statistics

According to the rules of the mathematical statistics [12] the uniformity of grain size distribution can be characterized by the empirical standard deviation of the mass (weight) distribution s according to the particle size:

$$s = \left(\sum_{i=1}^{m} f_i (x_i - \bar{x})^2 \right)^{1/2} . \quad (2)$$

It is important, that the standard deviation is not dimensionless number, but its unit is the same as of the particle size x_i.

There is another parameter in the mathematical statistics for determining the homogeneity of grain size distributions. This is the well known coefficient of variation $C.V.$, which is the relation of the standard deviation s and the particle mean size $\bar{x}$:

$$C.V. = k = \frac{s}{x} . \quad (3)$$

Usually it is given in decimal or percentage. It has the advantage that it is also dimensionless number.

Rosin-Rammler's coefficient of uniformity *n*

From the literature of the comminution [6] well known exponential function's exponent n:

$$R(x) = \exp\left(-\frac{x}{x_0}\right)^n \text{ and } D(x) = l - R(x) \quad [4]$$

that is dimensionless number, too. Illustrated as an undersize 'curve' $D(x)$ on RRSB net (DIN 66 145) is not else then the directional tangent of the distribution function's 'straight' line and could be read from the edge scale [4,5].

ROSIN-RAMMLER'S COEFFICIENT OF UNIFORMITY n AT DIFFERENT KIND OF FEEDS

The author of this paper gathered all the data of uniformity coefficients n available in the literature, that were obtained by other scientists carrying out sieve analysis with hammermill grinds [1,3,8-11,13,15] and put them in the Table 1.

Table 1. Uniformity coefficients n obtained by hammermilling different kind of feeds

Sign	Feed	Uniformity coefficient	Author
1.	Barley	1.4 - 2.1	Bölöni [10]
2.	Corn	1.72 - 2.33	Bölöni [8,9]
		0.88 - 1.45	Csermely [11]
		1.32 - 1.92	Henderson and Hansen [13]
		1.30 - 1.85	Pfost and Headley [15]
3.	Wheat	1.40 - 1.50	Akdeniz [1]
4.	Sorghum grain	1.50 - 2.0	Pfost and Headley [3]
5.	Alfalfa hay	1.16 - 1.54	Bölöni [8]

Remarks:
(1) Data were gained grinding different kinds of dry feed stuffs by different type of hammermills.
(2) The alien data originating from other scientists were determined by the author from their grain size distribution curves based on sieve analyses.
(3) Csermely's publication [11] concerns on quite wet corn grinding, having water content of 26-28 % w.b..

SOME TEST RESULTS ON GRITS' HOMOGENEITY

Investigations were carried out by help of a Hungarian hammermill, type D-24 (P= 19 kW), having pneumatic grind conveying system, with screens of ⌀ 3 - 5 - 12 mm hole diameters and without screen (No screen) grinding barley (water content=13.5 % w.b.) [10]. The feed flow rate varied between Q=100-3 000 kg/h. 116 p.c. sieve analyses were done and the Rosin-Rammler's coefficient of uniformity was determined by means of RRSB net (DIN 66 145).

Interdependencies of the uniformity coefficient *n*

First of all graphic normality test was carried out on probability net (Gauss paper). On that basis it was stated that the values of the uniformity coefficients n vary accidentally: n=1.4 -2.1 and the mean value or median of the distribution is n=1.705. Deviations from that are of probability origin.

After that, theoretical calculations were done by help of the Rosin-Rammler function (Eq. (4)), in the course of that n was kept constant (n=1.7) and the x_o parameters (the characteristic sizes of the grit) varied. As it is shown in Fig. 1 the undersize functions 'curve' $D(x)$ moves parallel by itself to the left during comminution, while the grinds' specific area is proportionally increasing. Well, there is no alteration in the homogeneity of grits. According to the author's experiences this might be the correct model for describing the fineness variation in hammermills by changing screens of different hole diameters etc.

In the second version x_o was kept constant (x_o=1.5 mm) and the uniformity coefficient n changed. In Fig. 2 it is to be observed, that all the undersize 'curves' $D(x)$ cross each other in the same point, where x_o=1.5 mm=const. and $D(x)$=0.632. Although with increasing of parameter n the homogeneity of grinds gets better, the grit's specific surface area decreases significantly!

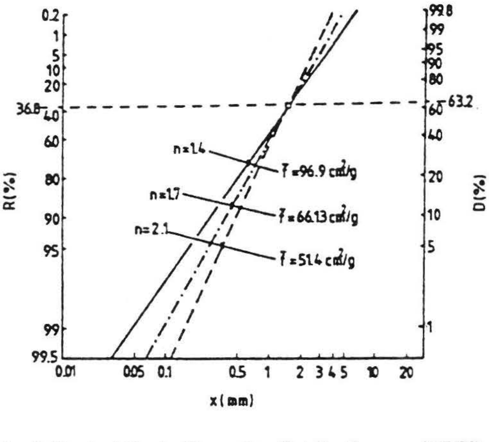

Fig. 2. Typical Rosin-Rammler distributions on RRSB-net, while x_o=const. and n parameter varies.

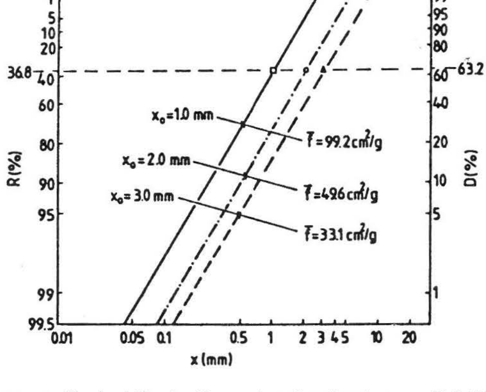

Fig. 1. Typical Rosin-Rammler distributions on RRSB-net, while n=const. and x_o parameter varies.

Interdependencies of the mathematical statistical parameters

First of all the standard deviations' actual numerical values s were illustrated as a function of the particle mean size $\bar{x}$ (Fig. 3). The relationship is very instructive, because it shows plausible, that the standard deviation of feed grain before grinding (s_g=0.6−0.8) increases after comminution all of a sudden, reaching a maximum (s_{max}=1.3 mm) and then decreases proportionally with average grain

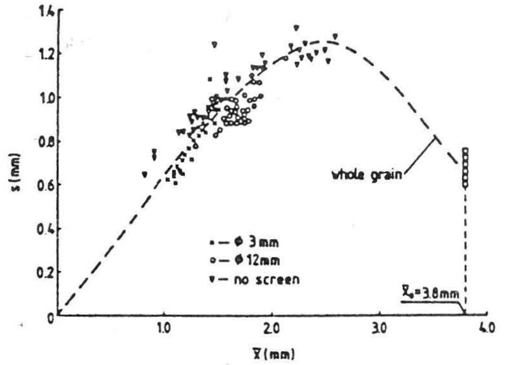

Fig. 3. The relationship of the particle mean size $\bar{x}$ and the standard deviation s with barley grinds.

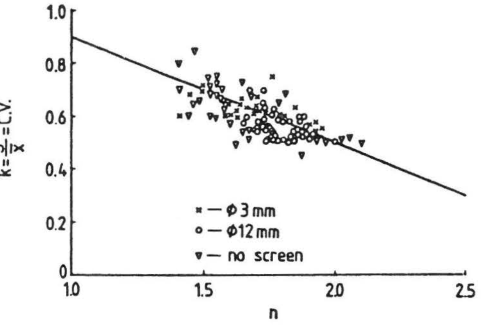

Fig. 4. The relationship of the coefficient of variation C.V. and Rosin-Rammler's uniformity coefficient n with barley grinds.

size $\bar{x}$. Its minimum value was $s_{\min}=0.6$ mm in the given case.

The variation of *C.V.* was also checked as a function of the particle mean size. It was stated for grinding with screens:

$$C.V. = k = 0.78 - 0.14\bar{x} \tag{5}$$

and having no screen

$$C.V. = k_{NS} = 1.0 - 0.20x \tag{6}$$

that follows from the above regularity (Fig. 3) $\bar{x}$ and *C.V.* are both probability variables and their interpedendence is of stochastic character.

Latestly the relation of *C.V.* and the uniformity coefficient *n* was investigated. The negative interdependence is to be observed in Fig. 4. They stand in a reversed relationship with each other:

$$C.V. = k = 1.3 - 0.4n \tag{7}$$

and

$$n = 3.25 - 2.5k. \tag{8}$$

These equations give good approximation.

It is to be mentioned yet, that the points of measurements with using screens and no screen are not to be separated from each other, which means that this relation of those two parameters is more general, than Eqs (6) and (7); may be because both of them are dimensionless numbers!

CONCLUSIONS

1. The uniformity of agricultural grind's grain size distribution is best to approach by the parameters, that are dimensionless numbers, like s_{gw}, b, k,$=C.V.$ and exponent n.
2. According to investigations carried out by the author and many other scientists the uniformity coefficient n of the Rosin-Rammler distribution is an appropriate physical characteristic of the agricultural grinds made by hammermills (e.g., barley, corn, wheat, grain sorghum, etc.) depending also upon the water content and the machinery parameters. It varies by the different feed grain sorts in general $n=0.88\text{-}2.33$ and especialy with barley $n_b=1.4-2.1$ while it is by cement only $n_c=0.5-1.2$.
3. The value of the Rosin-Rammler coefficient n changes like a probability variable in the individual probes and its distribution function is a skew straight line on the Gaussian paper.
4. In case of applying screens having different hole diameters the oblique straight line of the distribution functions on the RRSB-net move parallel to themselfes, if the exponent n=constant is and the characteristics size x_o changes. But if the size x_o=constant remains and the n parameters vary, the distribution curves will cross

each other in the point x_0 as inclined straight lines having different directional tangents.

5. The empirical standard deviation (S) of the grits' grain size distribution is in a close correlation with the particle mean size ($\bar{x}$), when $\bar{x}$ <2.0 mm and the standard deviation decreases proportionaly with the particle mean size.
6. The coefficient of variation ($C.V.$) or $k = \frac{\bar{x}}{s}$ and the Rosin-Rammler uniformity coefficient n have a negative stochastic relationship:

$$C.V. = k \cong 1.3 - 0.4\,n$$

and

$$n \cong 3.25 - 2.5\,k\,.$$

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