Results of evaluation of the efficiency of the working process of feed granulators

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Abstract. Existing studies in the field of application of the granulation process have proven the effectiveness of this process in eliminating the disadvantages that loose compound feeds have. The technology of granulation of compound feeds allows to ensure stable uniformity, improve sanitary and hygienic indicators, increase nutritional value, increase shelf life, as well as minimize losses during its transportation and distribution. Due to the growth in the production of compound feeds, continuous improvement of the equipment, machines and technologies used in granulation is required. We have made a comparative analysis of granulators for various types of indicators: economic, technical, technological, energy efficiency indicators. Three approaches were used to compare them: the rank approach, the standardization method, and the dimensionality reduction method. As a result, the optimization of the obtained results was carried out and, summing up the results of all three methods, the feed granulators were noted, which are the best in terms of the totality of all the parameters studied.

1 Introduction

The high productivity of farm animals directly depends on their complete and proper feeding. Food is a source of nutrients and energy that are necessary to maintain the normal functioning of the body, the development and reproduction of the animal. Therefore, the primary task in creating a solid feed base is to improve the process of preparing high-quality combined feeds.

Feeding animals with non-prescription feeds is unproductive, and also entails their high consumption when feeding. The structure of the compound feed should include as many nutrients of a certain quality and structure as possible [1].

The structure of loose compound feeds has a number of disadvantages, such as hygroscopicity, a tendency to delamination when they are moved, and a small bulk mass. This, in turn, negatively affects the quality of the finished feed.

The granulation process helps to eliminate these disadvantages of loose compound feed. To carry out this operation, feed processing enterprises must be equipped with specialized granulator machines [2-5]. Due to the growth in the production of compound feeds, continuous improvement of the equipment, machines and technologies used is required. The

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main goal of modernization will be to improve a number of indicators: economic, technical, technological and energy efficiency indicators [6-18].

In the Russian Federation, various domestic and foreign granulators are used, differing in their performance, total power of installed electric motors, cost, size, etc. The most common domestic granulators are: DG, KMRM, OGM, granulator «Bear», GCM, etc. Granulators of foreign production are also well-known: SZLH, ZLSP, ALB, etc.

We have made a comparative analysis of granulators for various types of indicators.

2 Materials and methods

All the compared equipment samples were compared according to the indicator system, which includes the following indicators:

- economic indicators (price, cost of delivery, cost of installation and commissioning, cost of repair kit);
- technical indicators (weight of the machine, its length, width and height);
- technological indicators (productivity);
- energy efficiency indicators (total capacity of installed power motors).

The general characteristics of technical alternatives for the selected indicators are presented in Table 1:

Table 1. Comparison of specific instances of equipment according to the formed system of indicators.

Stamp Granulator	Equipment indicators									
	Economic				Resource Efficiency					Energy Efficiency
					technical				technological	
	Price	Shipping cost	The cost of installation and commissioning	The cost of the repair kit	Machine weight	Length	Width	Height	Efficiency	Total power of installed electric motors
	rub	rub	rub	rub	kg	mm	mm	mm	tons/ hour	kW
DG-1B	1298000	71780	129800	125000	650	1418	750	1971	1.3	20.35
KMRM-250	624000	221720	62400	94000	720	1800	750	2200	1	23.85
SZLH - 400	2307000	764620	230700	248500	2500	3486	1325	2650	8	39.95
OGM-75 (08)	2006700	665100	200670	209800	2000	2300	1100	2200	1.2	77.95
DG-5	2457000	795120	245700	315000	2600	2140	1130	2 250	4.9	57.95
ZLSP-400	563977	147414	56398	54400	550	1520	600	1150	1.27	30
ZLSP 300 R-type	854000	95855	85400	128700	575	1400	600	1300	0.3	22
«COMBO» 350 AIR	601000	196398	60100	90600	550	1500	1000	1200	1.5	30
GK «Bear 3»	338000	91105	33800	35400	390	900	800	800	1	15
GKU-90 (ATM)	1950000	916310	195000	250000	2100	2350	1100	2300	3	93.7
GKM-250K	990000	303472	99000	95500	800	1920	750	1450	1.5	19.25
GM-280	222500	86920	22500	33600	350	1400	920	1200	0.9	15
KMRM-320	996770	491900	99700	150200	1850	2100	1644	1755	3	39.95

DG-3BУ	1202000	625213	120200	181000	1765	1700	1290	2100	3.5	39.25
ALB-350	2150000	581460	215000	225000	1900	1940	1825	2215	0.5	55

Comparison of alternatives according to the proposed criteria was complicated by the different dimensions of the indicators under consideration, the difference in the parameters of their distributions, in particular, the indicators of the scope.

To compare them, it is proposed to use three approaches:

- rank;
- standardization method;
- dimensionality reduction method.

3 Results and discussion

We conducted a comparative analysis of granulators using a rank approach. This method uses the idea underlying Wilcoxon's W-test [19] – the use of ranked values. We rank economic and technical indicators and energy efficiency indicators in ascending order (a lower value gets a lower rank), technological indicators – in descending order (a higher value gets a lower rank). The rank table will look like this (Table 2):

Table 2. Ranked comparison table of specific instances of equipment.

Stamp Granulator	**Equipment indicators**									
	Economic				**Resource Efficiency**					**Energy Efficiency**
					technical				**technological**	
	Price	**Shipping cost**	**The cost of installation and commissioni**	**The cost of the repair kit**	**Machine weight**	**Length**	**Width**	**Height**	**Efficiency**	**Total power of installed electric motors**
DG-1B	10	1	10	7	6	4	4	8	8	4
KMRM-250	5	7	5	5	7	8	4	10.5	11.5	6
SZLH - 400	14	13	14	13	14	15	13	15	1	10.5
OGM-75 (08)	12	9	12	11	12	13	9.5	10.5	10	14
DG-5	15	14	15	15	15	12	11	13	2	13
ZLSP-400	3	5	3	3	3.5	6	1.5	2	9	7
ZLSP 300 R-type	6	4	6	8	5	2.5	1.5	5	15	5
«COMBO » 350 AIR	4	6	4	4	3.5	5	8	3.5	6.5	8
GK «Bear 3»	2	3	2	2	2	1	6	1	11.5	1.5
GKU-90 (ATM)	11	15	11	14	13	14	9.5	14	4.5	15
GKM-250K	7	8	7	6	8	9	4	6	6.5	3
GM-280	1	2	1	1	1	2.5	7	3.5	13	1.5
KMRM-320	8	10	8	9	10	11	14	7	4.5	10.5
DG-3BУ	9	12	9	10	9	7	12	9	3	9

ALB-350	13	11	13	12	11	10	15	12	14	12

Summing up the ranked values, we get the resulting table: the granulator brand with the lowest sum of ranks will be the best for all the alternatives considered (Table 3).

Table 3. The final comparison table of specific instances of equipment by rank.

Stamp granulator	The total value of the sum of ranks	Place
DG-1B	62	6
KMRM-250	69	8
SZLH -400	122.5	13
OGM-75 (08)	113	11
DG-5	125	15
ZLSP-400	43	3
ZLSP 300 R-type	58	5
«COMBO» 350 AIR	52.5	4
GK «Bear 3»	32	1
GKU-90 (ATM)	121	12
GKM-250K	64.5	7
GM-280	33.5	2
KMRM-320	92	10
DG-3BУ	89	9
ALB-350	123	14

Thus, the best granulators – granulators with the same amount of ranks – can be called: the feed granulator "Bear 3", GM-280, the next in quality – ZLSP-400 and "COMBO" 350 AIR.

Further, a comparative analysis of granulators by standardization was carried out. All variables were reduced to standardized values by the formula:

$$y_i = (x_i - x') / \sigma \quad (1)$$

where σ - value of the standard deviation.

To ensure compatibility of the scales, technological indicators were taken with negative values (Table 4).

Table 4. Standardized comparison table of specific instances of equipment.

Stamp Granulator	Equipment indicators									
	Economic				Resource Efficiency					Energy Efficiency
					technical				technological	
	Price	Shipping cost	The cost of installation and commissioning	The cost of the repair kit	Machine weight	Length	Width	Height	Efficiency	Total power of installed electric motors
DG-1B	0.08	-1.08	0.08	-0.28	-0.77	-0.73	-0.79	0.34	0.44	-0.81
KMRM-250	-0.82	-0.56	-0.82	-0.64	-0.69	-0.10	-0.79	0.75	0.58	-0.66
SZLH -400	1.42	1.31	1.42	1.16	1.47	2.71	0.79	1.57	-2.84	0.03
OGM-75 (08)	1.02	0	1.02	0.71	0.86	0.74	0.17	0.75	0.48	1.66
DG-5	1.62	1.41	1.62	1.93	1.59	0.47	0.25	0.84	-1.32	0.80

ZLSP-400	-0.9	-0.82	-0.9	-1.1	-0.89	-0.56	-1.21	-1.14	0.45	-0.4
ZLSP 300 R-type	-0.51	-0.99	-0.51	-0.24	-0.86	-0.76	-1.21	-0.87	0.92	-0.74
«COMBO » 350 AIR	-0.85	-0.65	-0.85	-0.68	-0.89	-0.6	-0.11	-1.05	0.34	0
GK «Bear 3»	-1.2	-1.01	-1.2	-1.32	-1.09	-1.6	-0.66	-1.77	0.58	-1.04
GKU-90 (ATM)	0.95	1.83	0.95	1.17	0.99	0.82	0.17	0.93	-0.4	2.34
GKM-250K	-0.33	-0.28	-0.33	-0.62	-0.59	0.1	-0.79	-0.6	0.34	-0.86
GM-280	-1.35	-1.02	-1.35	-1.34	-1.14	-0.76	-0.33	-1.05	0.63	-1.04
KMRM-320	-0.32	0.37	-0.32	0.01	0.68	0.4	1.66	-0.05	-0.4	0.03
DG-3BУ	-0.05	0.83	-0.05	0.37	0.58	-0.26	0.69	0.57	-0.64	0
ALB-350	1.21	0.68	1.21	0.88	0.74	0.14	2.16	0.78	0.83	0.68

Accordingly, the smaller the standardized value, the better this piece of equipment according to the indicator under consideration. Thus, the smaller the sum of the standardized values, the better the granulator (Table 5).

Table 5. Summary table of comparison of specific instances of equipment by standardized values.

Stamp granulator	The total value of the sum of ranks	Place
DG-1B	-3.53	8
KMRM-250	-3.74	7
SZLH -400	9.03	12
OGM-75 (08)	7.42	11
DG-5	9.22	13
ZLSP-400	-7.46	3
ZLSP 300 R-type	-5.77	4
«COMBO» 350 AIR	-5.33	5
GK «Bear 3»	-10.29	1
GKU-90 (ATM)	9.74	15
GKM-250K	-3.96	6
GM-280	-8.75	2
KMRM-320	2.07	10
DG-3BУ	2.04	9
ALB-350	9.31	14

According to Table 5, the best alternative is the feed granulator "Bear 3", followed by GM-280, ZLSP-400, ZLSP 300 R-type.

Next, the analysis was carried out by the dimensionality reduction method – a modified principal component method. The concept of dimensionality reduction methods is based on the idea of obtaining a smaller number of new variables that are a linear combination of old variables while maintaining the overall variability of features. We applied the method described in [20] to standardized data. This algorithm is based on a singular decomposition of the matrix of parameters X, after which the following steps occur step by step: the largest eigenvalue of the matrix is calculated, the estimate of the main component is calculated, and, in conclusion, the eigenvalue is also calculated from the reduced matrix, etc.

In this case, one main component was obtained, and, accordingly, one new variable. According to the results of the algorithm, it will be expressed in terms of the old by the formula:

$$X = 0{,}46P + 0{,}46M + 0{,}403PNR + 0{,}288W + 0{,}549H, \quad (2)$$

where P – price of the granulator, rub.; M – cost of installation, rub.; PNR – cost of commissioning, rub.; W – width of the machine, m.; H – height of the machine, m.

Thus, according to the algorithm, the maximum degree of variability will be preserved. Meaningfully, the lower the value of the indicator X, the better a certain sample of equipment compared to others. The resulting comparison table of granulators is presented in Table 6.

Table 6. The final comparison table of specific instances of equipment when using the principal component method.

Stamp granulator	The total value of the sum of ranks	Place
DG-1B	0.31	8
KMRM-250	-0.41	7
SZLH -400	3.49	14
OGM-75 (08)	2.43	11
DG-5	3.68	15
ZLSP-400	-1.81	3
ZLSP 300 R-type	-0.99	5
«COMBO» 350 AIR	-1.17	4
GK «Bear 3»	-2.38	1
GKU-90 (ATM)	2.89	12
GKM-250K	-0.7	6
GM-280	-2.11	2
KMRM-320	0.8	9
DG-3BY	1.34	10
ALB-350	3.27	13

According to Table 6, the best alternative is the feed granulator «Bear 3», followed by GM-280, ZLSP-400, «COMBO» 350 AIR.

4 Conclusion

The conducted studies allow us to conclude that, summing up the results of all three methods, it can be noted that, according to the totality of all the parameters studied, the best sample is the feed granulator «Bear 3».

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