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QUALITY ANALYSIS OF BEAN THRESHING WITH PEG THRESHING UNIT

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A b s t r a c t. Most often bean threshing is performed with grain combines and then damage may be as high as 20 to 50 %. The main unit in grain combine causing the damage to beans is the threshing assembly. As can be seen from numerous research studies, the share of the threshing unit in the total damage caused in beans during threshing operation is about 63.0 - 68.0 %. Therefore, studies were intitiated in order to limit the mechanical damage to beans during harvest. The guilding assumption was that mechanical damage can be reduced mainly by tailoring the threshing unit design to the threshed bean and through performing the threshing operation at an optimum bean moisture content.

Among many tested threshing-unit designs, the best results were obtained in the multi-drum peg set. The basic idea for its operation consisted in combining the threshed mass with pegs of three revolvin drums. Three varieties of beans, significantly varrying in bean size, were subjected to threshing. Measurements were run at various bean moisture content (15.5-24.5 %). Macro- and micro-damage in seeds was evaluated, as well as the quantity of unthreshed beans. Such factors affecting threshing quality as the speed of threshing drums, relative positioning of pegs, drums and the beater plate, as well as the threshing capacity of the units were taken into account during measurements.

Results showed that the threshing unit uder study provided high-low seed-moisture levels (15.0-16.5 %). The lowest losses were obtained when beater-plate pegs were fully extended at an angle of 10 deg and drum pegs slanted at 30 deg. The optimum speed of the threshing drum for tested beans was 9.04 -10.17 ms^{-1}. The results of this study suggested the usability of the tested design for the threshing unit in agricultural practice.

K e y w o r d s: beans, mechanical damage, threshing

INTRODUCTION

In Poland the area seeded to edible pod plants has been getting smaller for a few years in a row. While 70 000 ha were under such plantings in 1980, the respective ackerage in 1991 was only 56 000 ha [9]. Beans were grown on 90 % of this area. One of the factors limiting the production of beans is the lack of suitable machines for harvesting this crop. During machine harvesting excessive losses ensue in the form of both uncollected beans and beans damaged mechanically. The bean threshing is most often performed with grain combine harvesters which cause damage to about 20-50 % of bean seeds [1,3,5,7]. The main assembly in the grain combine harvester responsible for causing the bean seed damage is the threshing assembly [2,4,6,8]. Therefore, a project has been undertaken in order to limit losses during bean threshinng, i.e., those in the threshing unit.

OBJECTIVE AND METHODS

The objective of this study was the development of suitable design of bean threshing unit and testing it for suitability for bean threshing. The idea of operation for this unit (ref. to Fig. 1) consists in moving and combining the threshed mass with the pegs of drum rotors and those of the beater plate. The mechanical damage to beans and the level of non-thresh were determined during tests versus such parameters as: the rotational speed of threshing drum rotors, positions of pegs in the drums, threshing-unit output and the bean-seed moisture content.

Measurements were taken while threshing the Igołomska bean variety. For more comprehensive testing and evaluation of the threshing unit under study, additional reference tests were carried out with other bean varieties, significantly differing in their 1 000-bean weights. The varieties under study weighed: Atut-191 g/1 000 beans, Igołomska -395 g/1 000 and Wiejska-648.5 g/1 000 beans (seeds). The measurements were taken in laboratory conditions on a stationary test rig.

Technical data of threshing unit:

- width of threshing machine - 500 mm,
- diameter of drum rotors - 540 mm,
- peg lengt - 110 mm,
- pegspacing - 70 mm,
- size of beater-plate holes - elongated 35 x 10 mm.

Designations, as used in this paper:

p - non-thresh,
q - output of threshing unit,
u - mechanical damage to beans/seeds,
v - circumferential speed of threshing drum rotors,
α - inclination/slant angle of beater-plate pegs,
β - inclination/slant angle of drum rotor pegs,
l - peg protrusion length .

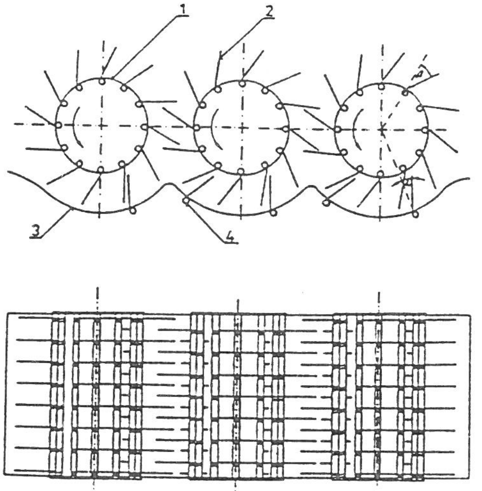

Fig. 1. Diagram of peg/drum threshing unit: 1 - drum, 2 - drum peg, 3 - perforated beater plate, 4 - beater-plate peg.

RESULTS

Effect of beater-plate peg position on threshing quality

Determinations run during tests were to find out the effect the peg protrusion length and peg inclination had on the damage to beans and on the level of non-thresh (Fig. 2).

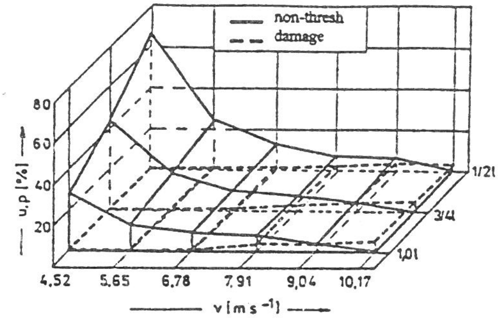

Fig. 2. Effect of beater-plate peg pull-out on the resulting mechanical damage to seeds and non-thresh level at various circumferential speeds of threshing drums.

The obtained data show that increase of peg protrusion length had first of all a positive effect on non-thresh reduction with an accompanying slight rise in the quantity of damaged beans/seeds. The variance analysis showed that the (wider) differentiation of beater-plate peg length (*l*) affected the non-thresh significantly only in the lower range of circumferetcial speeds of threshing drum rotors (4.52 and 5.65 ms^{-1}), while the effect on the level of mechanical damage to beans was significant only in the higher range of rotor speeds (7.91 to 10.17 ms^{-1}). At drum rotor speed of 10.17 ms^{-1} the damage to seeds amounted to 5.8 % for 1.0 l, 5.5 % for 3/4 l, and 4.0 for 1/2 l. The change in peg length at the lowest circumferential speed of threshing drum rotors, i.e., 4.52 ms^{-1} brought about the difference in non-thresh from 28.4 % to 66.4 %. The change in peg protrusion length at threshing rotor speed of 6.78 ms^{-1} had no significant effect on any of the characteristics under study. The effect of beater-plate peg inclination on threshing quality was tested at three values of the angle

α, i.e., 10^{o}, 20^{o} and 30^{o}. Variations of peg inclination/slant angle showed limited influence on bean threshing quality (Fig. 3).

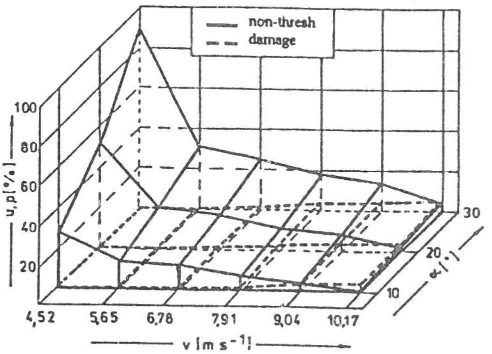

Fig. 3. Effect of beater-plate peg inclination angle on bean threshing quality at various circumferential speeds of threshing drums.

At higher speeds of threshing drums (v=7.91 ms^{-1}, 9.04 ms^{-1}, and 10.17 ms^{-1}), significant differences were recorded only in bean damage while at lower speeds (v=4.52 ms^{-1}, 5.65 ms^{-1}, and 6.78 ms^{-1}) only the non-thresh values were significantly affected. The change in inclination angle from $\alpha=10^{o}$ to $\alpha=30^{o}$ at drum rotor speed of 4.52 ms^{-1} resulted in only a slight reduction of damage 0.6 %) but also in a significant rise in non-thresh, from 28.4 to 90.9 %. At maximum speed of drum rotors, 10.17 ms^{-1}, the damage was reduced from 5.0 to 4.0 % while the non-thresh rose to 4.2 %.

Effect of threshing drum peg inclination on threshing quality

The differenitation in the inclination of threshing drum pegs from 0^{o} to 30^{o} affected the change in resulting damage and non-thresh levels to various degrees and depended on circumferential speeds of threshing drums (Fig. 4). Significant variations in non-thresh values were recorded at the lowest speed of threshing drums (v=4.52 ms^{-1} and 5.65 ms^{-1}). At the speed of v=4.52 ms^{-1} the increase of peg inclination/slant angle from 0^{o} to 30^{o} resulted in the rise in non-thresh from 23.0 to 64.8 %, accompanied by a slight reduc-

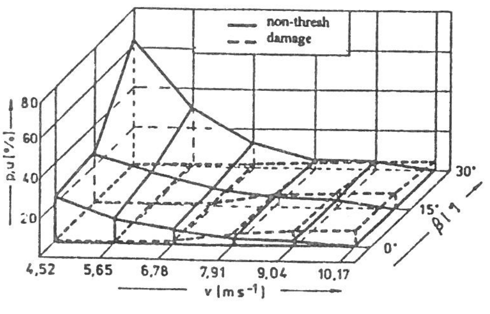

Fig. 4. Effect of threshing drum peg inclination angle on bean threshing quality at various circumferential speeds of threshing drums.

tion in bean damage. At the highest tested speeds of v=9.04 ms^{-1} and 10.17 ms^{-1} the change of peg inclination/slant angle brought about very different levels of damage. Increase of angle β from 0^{o} to 30^{o} at drum speed v=10.17 ms^{-1} resulted bean damage reduction from 9.2 do 5.0 %. The highest threshing quality (bean damage of 5 %, non-thresh of 0 %) was achieved at drum rotor speed of 10.17 ms^{-1} and peg position at the angle of $\beta=30^{o}$.

Effect of threshing output in peg/drum threshing unit on bean threshing quality

From the obtained data (Fig. 5) it can be seen that the increase in threshing output from 1.5 kgs^{-1} to 4.5 kgs^{-1} resulted in both higher non-thresh and in more damage to beans. Significant rise in non-tresh was

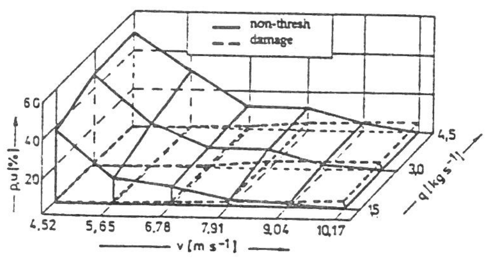

Fig. 5. Effect of threshing unit output on the resulting mechanical damage to seeds and non-thresh level at various circumferential speeds of threshing drums.

observed at lower speeds of threshing drums, i.e., at v=4.52 and 5.65 ms^{-1}.

At a speed of 10.17 ms^{-1} the losses due to non-thresh did not occur. Significant differences in the damage to bean seeds were found all over the range of circumferential speeds of threshing drums except the lowest one (4.52 ms^{-1}). The widest differences in the level of damage were recorded at the speed of 10.17 ms^{-1} (while it was 4,0 % at the output of q 1, it rose to 5.8 % at q 3).

Evaluation of performace of peg threshing unit applied for threshing beans of various varieties and with various moisture content

The tests of performance of peg/drum threshing unit for various bean moisture content were carried out while threshing the Igołomska beans. The other varieties used for testing this unit were: Atut small-sead variety and Wiejska large-seed bean. Tests were run with maximum pull-out of beater-plate pegs inclined at an angle $\beta=10^o$ and drum pegs inclined at an angle $\beta=30^o$. During comparison tests the speeds of threshing drum rotors were fixed at 10.17 ms^{-1}. When threshing beans with moisture content ranging from 15.0 % to 24.2 % the damage to beans varied within 2.6 to 6.0 %, while non-thresh varied from 0.8 % to 5.6 % (Fig. 6). The non-tresh share rose significantly with the increase of bean moisture content from 18.6 % to 21.0 %. The moisture content of pods varied in this case from 8.8 to 9.5 %. The losses were at a minimum at bean moisture content between 16.5 % and 18.6 %. Micro-damage dominated the damage scene with 2.4 to 5.3 %. The results achieved at threshing the chosen varieties of beans are shown in Fig. 7. The achieved data confirmed high quality of threshing with the peg/drum threshing unit. The non-thresh did not exceed 0.8 % and damage to beans was 2.5 %, with micro-damge. The Atut small-sead bean variety proved most resistant to mechanical damage; while the Wiejska large-seed variety was least resistant.

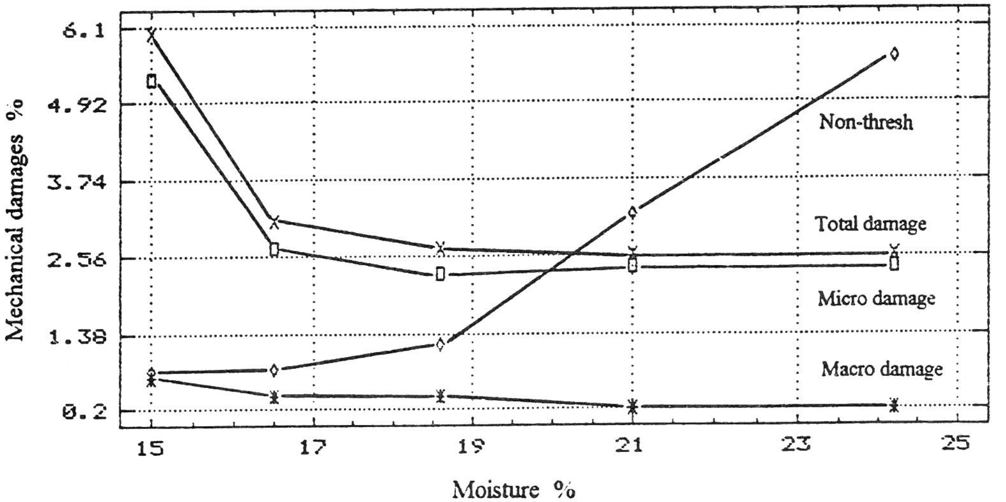

Fig. 6. Threshing quality versus bean moisture content.

CONCLUSIONS

1. The variation of beater-plate peg lengths, as well as that of the values of inclination angle of pegs in beater-plate and drum rotors resulted in significant differences only in non-thresh values at low speeds (4.52 to 6.78 ms^{-1}). Differences in damage to beans/seeds were insignificant.

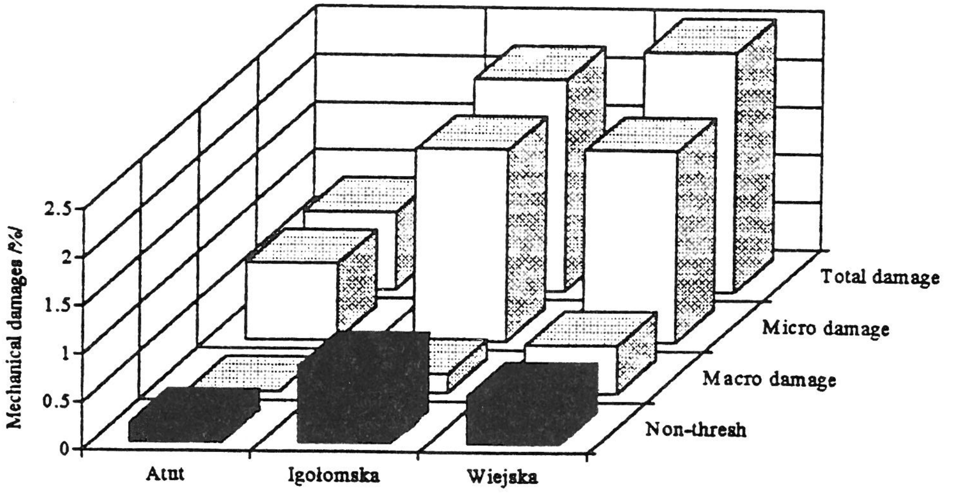

Fig. 7. Threshing quality for different bean varieties.

Table 1. Statistical evaluation of the effect of operational values of the threshing unit on the behaviour of characteristics under study

Characterisitcs under study	Cricumferential speed of threshing drum rotors (ms^{-1})					
	4.52	5.65	6.78	7.91	9.04	10.17
			Peg protrusion length			
Mechanical damage to beans	-	-	-	++	++	++
Non-thresh	++	+	-	-	-	-
			Inclination angle of beater-plate pegs			
Mechanical damage to beans	-	-	-	+	+	+
Non-thresh	+	+	+	-	-	-
			Inclination angle of drum rotor pegs			
Mechanical damage to beans	-	-	-	+	+	+
Non-thresh	+	+		-	-	-
			Output of threshing unit			
Mechanical damage to beans	-	+	+	+	+	+
Non-thresh	+	+		-	-	-

++ highly significant effect (significance level of 0.01), + significant effect (significance level of 0.05), - no significant effect.

2. Increase of threshing-unit output from 1.5 to 4.5 kg s^{-1} had significant effect only on the rise of non-thresh at speeds of 4.52 and 5.65 ms^{-1}. At other speeds the variations of bean damage and those of non-thresh were insignificant. On the other hand, the damage to seeds rose significantly over the whole range of tested speeds, except the lowest one, i.e., 4.52 ms^{-1}.

3. The lowest losses (damage to beans plus non-thresh) were achieved when threshing beans with moisture content in the range of 16.5-18.6 %.

4. High quality of threshing process (damage=2.5 %, non-thresh=0.8 %) of various varieties of beans confirms good suitability of tested threshing unit for bean threshing.

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