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REFINEMENT AND EVALUATION WHEAT STRAW COMBINE FOR BETTER STRAW QUALITY

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Abstract: Straw combine is very popular machine in Punjab for the retrieval of wheat straw. It was observed that quality of wheat straw obtained from straw combine is inferior due to more dirt content as compare to harambha thresher. Therefore, the straw combine was developed with straw bruising and sieving system for the removal of dirt. Dirt was quantified by total ash content and acid insoluble ash. Field evaluation of the modified straw combine and laboratory analysis of collected sieved straw sample was carried out. Two level of concave bar spacing (10 and 14 mm), three feed rates (14, 16.5 and 19 $q \cdot h^{-1}$) and three cylinder speeds (28.45, 32.25 and 36.04 $m \cdot s^{-1}$) were selected as operational parameter. It was observed that mechanical sieving of straw was well enough for the separation of dirt. Percent reduction of total ash content and acid insoluble ash due to sieving increases with decrease in feed rate and increase in concave bar spacing. Average straw length and split straw percentage was found to well within acceptable level at 14 mm concave bar spacing. Net specific fuel consumption was found to be decreases with increase in feed rate and concave bar spacing and increases with increase in cylinder speed.

Key words: *straw combine, average straw length, split straw percentage, total ash content, acid insoluble ash.*

INTRODUCTION

The production and productivity is directly related with farm mechanization i.e. power availability. The availability of power in Punjab is 3.5 $kW \cdot ha^{-1}$, which is highest

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in the country while average power availability in agriculture for whole country is 1.5 kW·ha^{-1} [5]. This mechanization was achieved by the developing various machinery based on crop and need. Straw combine is a machine which cut, collect, bruise and convey the straw in wire mesh trailer. A straw combine essentially consist of five main units, namely stubble cutting unit, feeding unit, straw bruising unit, blowing unit and straw collection unit which contains a trailer enclosed by wire mesh to collect bhusa during straw combine operation and to separate dust particles. The machine can be operated by tractor of 40-50 hp. The power is transmitted from PTO shaft. Average height of cut stubbles was 48 mm above the ground. About 96% of the total mass passing through the straw combine was chopped into lengths of < 50mm and only 4% of the mass was > 50 mm long. Average straw recovery was about 52% and recovered wheat grain amounting to 22 kg·ha^{-1} [2]. But it was observed that the straw harvested by straw combine contains soil dirt which increases total ash content and acid insoluble ash which is harmful for the animal health. As per recommendation of Department of Animal nutrition GADAVASU, Ludhiana, Punjab, ash content should not exceed 7-8 % and acid insoluble ash should not exceed 4-5% [1]. Whereas, in case of sample obtained from straw combine, values of ash content (13.72%) and acid insoluble ash (6.61%) exceeded the recommended values, thus indicating that the straw produced by straw combine contain more dirt as compared to harambha thresher.

A study on separation of dirt content from bruised wheat straw was done by Bhardwaj (2008) to investigate the design parameter for the development of dirt separation system for wheat straw combine. It was observed that sieving is best method for dirt separation from bruised straw. To attach sieving system on the existing straw combine, blower of the machine has to be removed. Preliminary trails have shown that in the absence of blower, material does not come out of the threshing/ bruising drum and machine chokes. Therefore, there is a need to modify a straw bruising system of existing machine to fit a sieving system on it. Therefore, the study was undertaken to improve the performance of straw combine by developing a new straw bruising system and by providing a sieving system in straw combine.

MATERIAL AND METHODS

A tractor operated modified straw combine was developed in the department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana, Punjab.

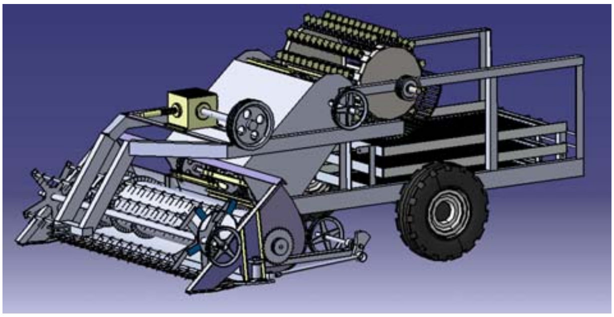

Figure 1. Computer aided 3D model of conceptual modified wheat straw combine

Before developing actual working machine, computer aided 3D model of conceptual machine was made to give exact idea for fabrication. The performance and evaluation studies were conducted in the research farm of Punjab Agricultural University, Ludhiana, during May-June, 2013.

General descriptions of the modified wheat straw combine

The improved wheat straw combine was fabricated with the following modifications:

1. Straw bruising unit with chain type feeding system.
2. A rectangular sieving system for sieving of bruised straw which was absent in existing straw combine.
3. Blower unit was absent.

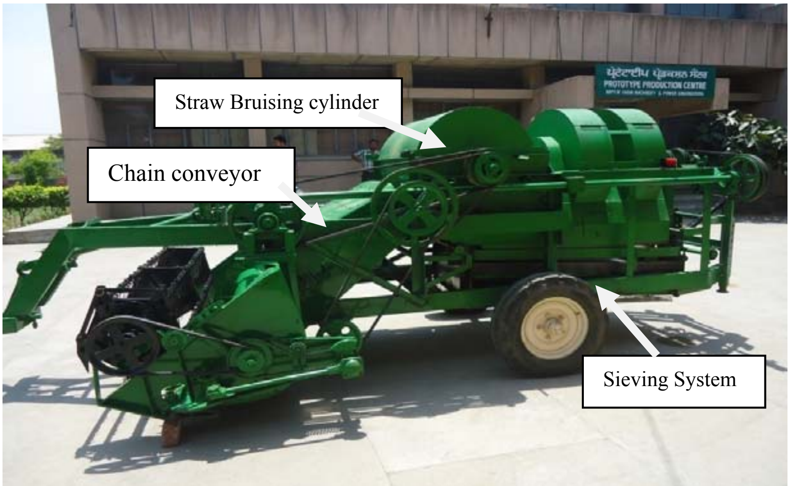

Figure 2 Modified wheat straw combine

Other components of modified straw combine similar to that of the existing straw combine includes; cutter bar, reel, platform auger, type of bruising cylinder i.e. serrated tooth type, and the supporting frame. The cutting unit has a same cutting width to maintain equal capacity as the existing one. A platform auger is located below the chain type feeding conveyor to convey the material. The chain type feeding conveyor has same as combine harvester which was absent in the existing straw combine. It is constructed to convey the feed into the bruising cylinder. The straw bruising cylinder was made up of no. of serrated blades arranged on steel bars. This cylinder drum is mounted on the frame with bearing and is rotated in a perforated trough-like member, called the “Concave”. The width of the bruising unit was kept smaller than the existing straw combine. This was to enable the proper feeding of straw from chain conveyor to cylinder which leads to easy bruising. The sieving system was placed exactly at the bottom of bruising cylinder and it consists of two sieves one above the other. Sieving unit catch the bruised straw from cylinder and separate the dirt from the straw through a reciprocating motion provided by the main source of power of the straw combine. The blower unit was removed. The straw was collected at end of the sieve. The transmission unit consists of a gear box, cylinder pulley, a cutting unit pulley and a shaker pulley. The 65 hp tractor was used for evaluating the modified straw combine. The machine was operated by PTO of tractor. By using gearbox with ratio 1:1, power was transmitted to the cutting, collecting and bruising components of straw combine. The straw combine has a structural frame on which all other components were mounted. The brief specifications are given in Tab. 1.

Table 1 Specification of modified straw combine

Sr. No.	Parameter	Specification
1.	Power source	2 p tractor
2.	Overall dimension of machine Length Width Height	 5050 2320 1820
3.	Chain conveyor	
	Opening width Front opening height Rear opening height	1030 500 260
4.	Bruising drum	
	Type Width Tip diameter of cylinder with blade No. Of bars No. Of blades and their spacing on each bar	Serrated tooth type blade 1003 725 12 13,76
5.	Baffle plate	
	Type No. Plate Location	Serrated type blade 1 Adjacent to concave
6.	Straw cleaning sieve	
	Type of sieve shaker Type and size of sieves Effective size of sieve	Reciprocating type Wire mesh, 1550 x 860 1530 x 820
	Hole dia. Upper sieve Lower sieve	 4 0.208 mm
	Inclination towards the end	8°

All line dimensions in mm

Evaluation Procedure

The independent variables that affect the machine performance were included in the study i.e. concave bar spacing, cylinder peripheral speed and feed rate. Feed rate of the straw combine was dependent upon the width of cut, crop density, forward speed, and stalk cut length. In this study feed rate was varied with machine forward speed. The present study was related to the different aspects of quality of bruised straw obtained from newly fabricated straw combine. Therefore, straw quality and dirt content were included as dependent variables. Apart from this net specific fuel consumption was a very important variable which has an obvious importance. It is ratio of net fuel consumption and feed rate. Net fuel consumption is the difference between actual fuel consumed for operation of machine at load and no load. In order to assess the dirt content of bruised straw, two types of tests namely; total ash content and acid insoluble ash were conducted. Straw quality was determined on the basis of average straw length and percent splitting of bruised straw. For measuring fuel consumption, fuel meter was used. The experiment was planned with a Factorial *CRD* to analyze the effect of three independent variables on the dependent variables. On the basis of level of independent parameter, there were 18 (3×3×2) treatment combinations in the complete study. Each treatment of field evaluation was replicated three times. The length of treatment was decided 50 m whereas effective cutting width was 1.75 m. The wheat harvested field area i.e. 4725 m² (54×50×1.75) was divided into three equal block of area 1575 m² for three replication i.e. each experiment was replicated in three different block for its replication. Each block was again divided into two parts in which two concave bar spacing C1 i.e. 10 mm and C2 i.e 14 mm were used. Again each part was divided into 9 equal of strip i.e. 1.75 × 50 m to conduct experimental treatment.

RESULTS AND DISCUSSION

Effect of concave bar spacing, cylinder speed and feed rate on net specific fuel consumption

Analysis of variance showed that concave bar spacing, cylinder speed and feed rate were significant effect at 5% level of significance. Fig. 3 shows that the net specific fuel consumption increases with increase in cylinder speed. This is because of more impact force by high speed blade of cylinder relative to the material. The highest net specific fuel consumption was observed at lower feed rate and higher cylinder speed at concave bar spacing 10 mm.

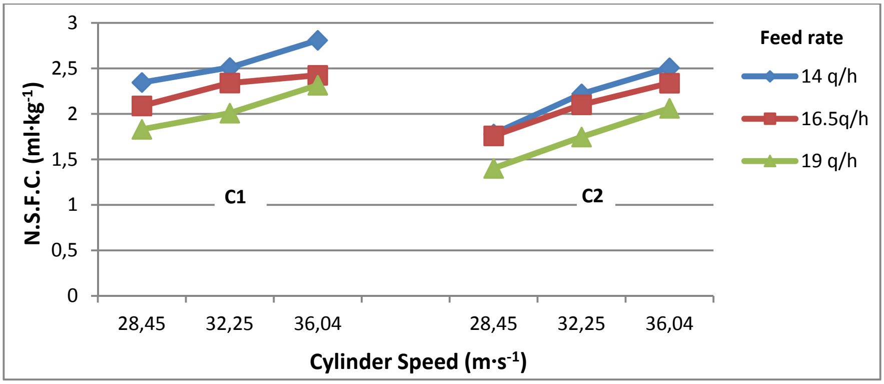

Figure 3. Effect of independent variables on net specific fuel consumption

During operation, net fuel consumption increased with increase in feed rate, because at higher feed rate, the bruising cylinder has to handle more straw mass. I t was supported by Thakur and Garg, 2007 [6]. But decrease in net specific fuel consumption was due to the reason that net fuel consumption increased with decreasing rate i.e. increase in net fuel consumption was relatively lesser as compared to increase in feed rate. From Fig. 3, it is clear that the net specific fuel consumption decreased with increase in concave bar spacing. The obtained result supported by Venkata *et al* (2009) [7] in case of total and specific energy. As concave bar spacing increases, lesser resistance was offered for the movement of straw in the cylinder. On increasing concave bar spacing from 10 mm to 14 mm, net specific fuel consumption reduces by 0.566 ml·kg^{-1} at feed rate of 14 q·h^{-1} and cylinder speed of 28.45 m·s^{-1}. This was due to wider concave opening allow early and easy passing of bruised straw through the concave which cause less straw crushing. It also results in reduction of net specific fuel consumption.

Effect of concave bar spacing, cylinder speed and feed rate on average straw length of bruised straw

From the statistical analysis it was revealed that the concave, cylinder speed and feed rate significantly affected average length of straw at 5% level of significance. All interactions were not significant at 5% level of significance.

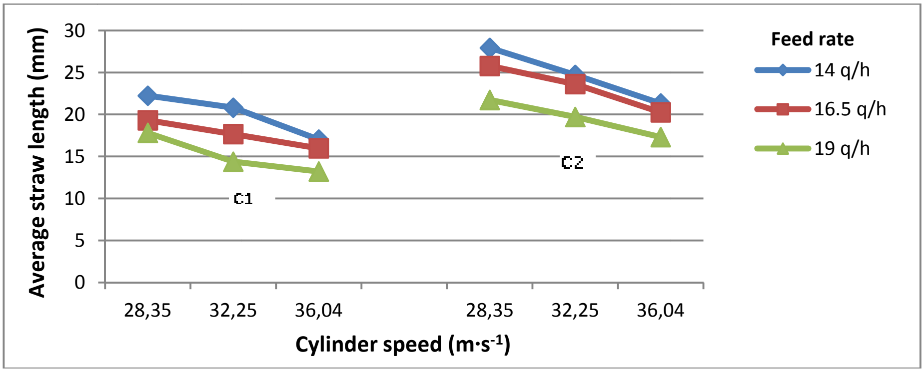

Figure 4. Effect of independent variables on average straw length

It can be seen from the Fig. 4, the cylinder speed and feed rate, have indirect relation with average length of bruised straw. This may be due to the fact that amount of straw to be cut increased by increased feed rate and also due to higher feed rate straw was properly compressed which lead to less slippage of straw and more retention time of crop in concave meanwhile, the number of cut per unit time increases and this lead to decrease in the average length of bruised straw and vice-versa. Similar kind of effect was observed by Singh *et al* 2011 [4]. The highest average length of bruised straw in case of *C1* was found to be 20.23 mm at cylinder speed of 28.45 m·s^{-1} and feed rate of 14 q·h^{-1}. In contrast, the lowest average length of bruised straw was found to be 12.22 mm at cylinder speed of 36.04 m·s^{-1} and feed rate of 19 q·h^{-1}. Average length of bruised straw in case of *C1* was acceptable (≤ 25 mm and c.v. ≤ 40%) only at the feed rate of 14 q·h^{-1} in the combination with cylinder speed of 28.45 and 32.25 m·s^{-1} and at feed rate of 16.5 q·h^{-1} in the combination with cylinder speed of 28.45 and 32.25 m·s^{-1}. Similar kind of result obtained for concave bar spacing of 14 mm. It was observed that the high value average length of bruised straw was found to be (25.26 mm) at cylinder speed of 28.45 m·s^{-1} and feed rate of

14 q·h^{-1} and quite the reverse, the low value average length of bruised straw was found to be (16.07 mm) at cylinder speed of 36.04 m·s^{-1} and feed rate of 19 q·h^{-1}. The obtained result in case of concave bar spacing was in line with Venkata *et al* 2011 [8]. At feed rate of 14 q·h^{-1} and cylinder speed of 28.45 m·s^{-1}, average length of bruised straw is not acceptable because C.V. is greater than 40%, which is beyond the permissible limits.

Effect of concave bar spacing, cylinder speed and feed rate on straw split percentage of bruised straw

Analysis of variance revealed that the effects of the concave bar spacing, cylinder speed, and feed rate significantly affects on split straw percentage at the 5% level of significance. Among the all interaction, first order interaction between concave and cylinder speed was significant at 5% of confidence level. It was observed that at *C1*, by increasing the cylinder speed from 28.45 to 36.04 m·s^{-1}, split straw percentage increased from 93.49% to 96.96%, from 94.27% to 97.95%, and from 95.26% to 98.43% at the feed rates of 14, 16.5 and 19 q·h^{-1} respectively. Similarly, by increasing the feed rate from 14 to 19 q·h^{-1}, split straw percentage increased from 93.49 to 95.25%, from 95.02 to 96.55%, and from 96.96 to 98.43% at the cylinder speed of 28.45, 32.25 and 36.04 m·s^{-1} respectively.

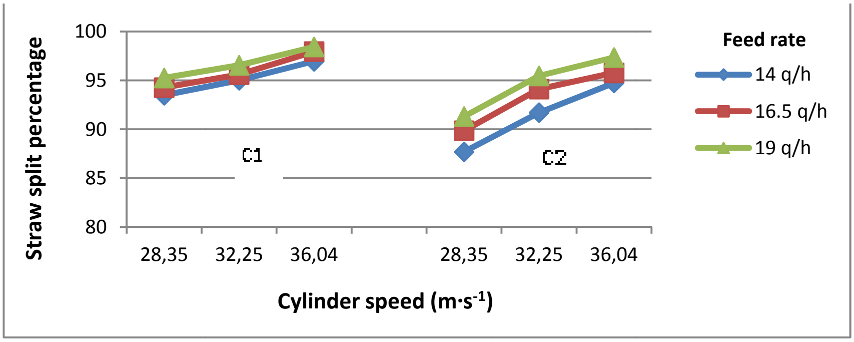

Figure 5 Effect of independent variables on split straw percentage

At concave *C2*, similar trend was observed. The obtained results for *C2*, indicates that on increasing cylinder speed from 28.45 m·s^{-1} to 32.25 m·s^{-1} and at fixed feed rates of 14, 16.5 and 19 q·h^{-1} split straw percentage increased from 87.69 to 94.74%, 89.85 to 95.78% and 91.31 to 97.35% respectively. Again, by increasing feed rate from 14 to 19 q·h^{-1}, the percentage of split straw was increased from 87.69 to 91.31%, 92.71 to 95.47% and 94.74 to 97.35% at fixed cylinder speeds of 28.45, 32.25 and 36.04 m·s^{-1} respectively. The straw split percentage obtained at concave bar spacing of 14 mm and cylinder speed of 28.45 m·s^{-1} for all level of feed rate was not acceptable due to split straw percentage was < 92%.

Effect of independent parameter on reduction of total ash content

Statistical analysis indicates that there is a significant effect of the feed rate and concave bar spacing on the dependent variables i.e. reduction of total ash content while cylinder speed is not affecting significantly at 5% level of significance. The first order interaction between concave bar spacing and cylinder speed was significant.

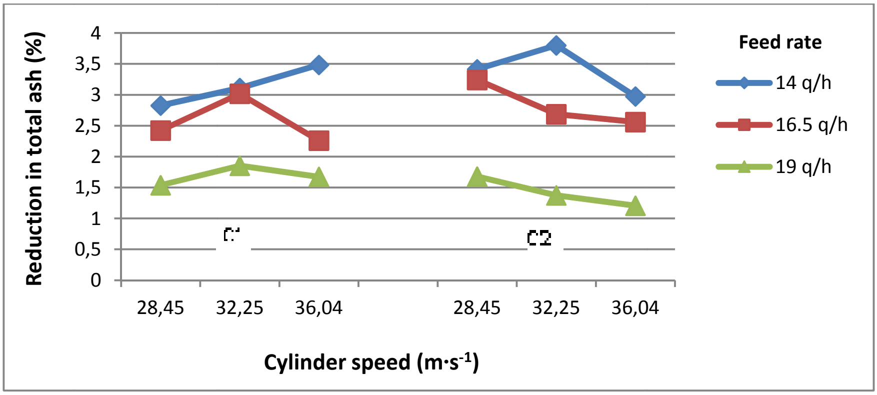

Figure 6. Effect of independent parameter on reduction of total ash content

Effect of independent parameter on reduction of acid insoluble ash

The statistical analysis shows that concave bar spacing and feed rate were significant effect on the reduction of acid insoluble ash. Also, the first order interaction of concave bar spacing and cylinder was a significant effect. With increase in feed rate from 14 q·h^{-1} to 19 q·h^{-1}, percent reduction of acid insoluble ash decreases. This was because of same reason as observed for total ash content. In case of concave bar spacing of 10 mm and 14 mm, it was found that maximum reduction in total ash content was observed at 14 mm concave bar spacing as compared to 10 mm concave bar spacing.

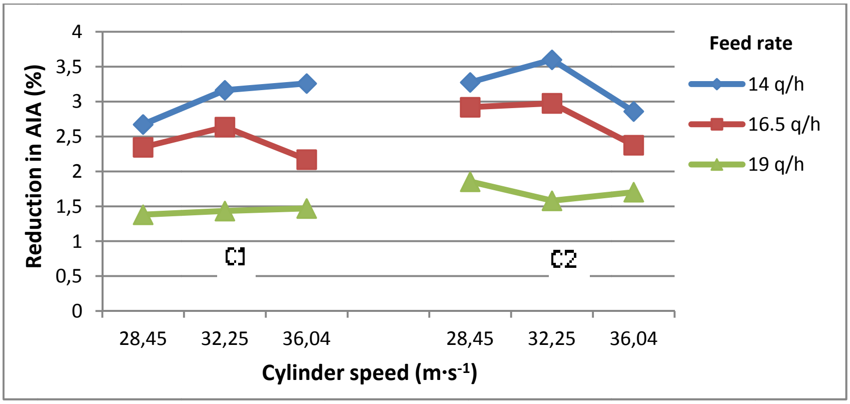

Figure 7. Effect of independent variables on reduction of acid insoluble ash

This is because of larger concave opening which gives early exit to chopped straw through the concave and thereby decreasing the fine stuff in straw. Moreover, straw bruising was avoided which result in larger straw length. Larger straw reduce resemblance between chaff and dirt which may differentiate straw and dirt which help for better separation. The lowest value of acid insoluble ash in bruised straw was found to be 5.08%.

CONCLUSIONS

1. Net specific fuel consumption was decreases with increase in feed rate but increase with cylinder speed. The maximum net specific fuel consumption observed at concave bar spacing of 10 mm, 14 $q \cdot h^{-1}$ feed rate and 36.04 $m \cdot s^{-1}$ cylinder speed.
2. Average straw length of concave bar spacing of 14 mm (C2) was well within acceptable range i.e.≤25 mm along with ≤ 40% C.V. and splitting of straw (≥95%) for all combination of cylinder speeds of 32.25 and 36.04 $m \cdot s^{-1}$ except at feed rate of 14 $q \cdot h^{-1}$ and cylinder speed of 28.45 $m \cdot s^{-1}$.
3. Maximum reduction in percent total ash content and acid insoluble ash was observed at 14 $q \cdot h^{-1}$ feed rate and 14 mm concave bar spacing due to sieving of straw.
4. The best performance combination of independent variables was at concave bar spacing of 14 mm, feed rate of 14 $q \cdot h^{-1}$ and cylinder peripheral speed of 32.25 $m \cdot s^{-1}$ for the best quality straw, maximum reduction as well as minimum dirt content (total ash content and acid insoluble ash).

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UNAPREĐENJE ŽITNIH VRŠALICA U CILJU POBOLJŠANJA KVALITETA SLAME

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Sažetak: Žitne vršalice su veoma popularne u Punjab oblasti u Indiji. Primećeno je da je kvalitet slame nakon ubiranja klasičnim žitnim kombajnom, lošiji zbog većeg prisutva nečistoća, u poređenju sa žitnom vršalicom. Iz tog razloga se radilo na konstrukciji kombajna za slamu koji je opremljen uređajem sa čišćenje i prosejavanja slame. Prilikom ispitivanja kvaliteta rada, količina nečistoće odstranjena iz slame, je određena preko količine pepela nakon sagorevanja i sadržaja, u kiselini, nerastvorenog pepela. Poljsko ispitivanje je takođe sprovedeno a uzorci slame su doneti na labaratrijsko ispitivanje. Dva nivoa rastojanja rešetke (10 i 14 mm), tri protoka (14, 16.5 i 19 $q \cdot h^{-1}$) i tri brzine bubnja (28.45, 32.25 i36.04 $m \cdot s^{-1}$) su uzeti kao parametri rada. Uočeno je da je mehanički sistem prosejavanja slame zadovoljavajući u slučaju otklanjanja nečistoća. Procenat smanjenja ukupne količine pepela i količine pepela nerastvorenog u kiselini, se povećava sa smanjenjem protoka i sa smanjenjem rastojanja između rešetki sita. Prosečna dužina slame i udeo polomljene slame su bili u prihvaltjivim granicama kod minimalnog rastojanja između rešetki sita od 14 mm. Ukupna specifična potrošnja goriva se smanjivala sa povećanjem protoka mase i rastojanja između rešetki, dok se, sa povećanjem brzine obrtanja bubnja, povećavala.

Ključne reči*: žitna vršalica, prosečna dužina slame, polomljena slama, ukupan sadržaj pepela, u kiselini ne rastvoriv pepeo*

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