Modification of a combine harvester rice threshing device

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Abstract: Rice threshing is one of the important factors affecting grain losses, quality and quantity. The wearing of the secondary threshing drum forks and bearing occurs crop blockage inside the threshing housing that lowers the combine harvester field capacity and increases the total grain losses. To overcome this problem, this study aimed to modify the combine harvester rice threshing device by replacing the secondary drum forks with knife blades. The combine harvester was evaluated using the modified drum, compared with the original drum. The tested treatments were rice grain moisture content (20%, 23% and 25% d.b.) and operational time (50, 100, 150 and 200 hrs.). The experiment was established and statistically designed as a factorial completely randomized block design with three replications. The obtained results revealed that modified secondary drum achieved lower values of wearing rate, lower values of rice grain total losses and higher values of threshing efficiency, compared with the original drum. So, it is recommended to use the modified secondary drum, especially at 23% grain moisture content and 50 hrs. operating time.

Keywords: combine harvester, threshing, rice

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1 Introduction

Rice threshing is defined as a grain separation from the panicles. It follows crop harvest and whatever pre grain drying. It was carried out in the field using simple tools where panicle bunches are beaten against a wooden bar log, bamboo table or stone. It is very tedious and time consuming. Also, rice threshing was conducted using animals or vehicle passage, causing grain breakage that reduces the product quality and fosters subsequent losses from the action of insects and moulds (Alizadeh and Bagheri 2013). This situation has compelled farmers to shift to the use of mechanical threshers which can enable more timely harvest with lower losses. Firstly, the mechanical threshing was done using the pedal thresher which is operated manually (IRRI, 2015). Thereafter, the motorized thresher was used (Alex, 2016). Then, threshing can be carried out simultaneously, using combine-harvester. Which performs reaping, threshing and winnowing operations in a single pass. So, it reduces the operational costs and facilitates timely operation (Singh et al., 2020). In addition, rice combine harvester could lower harvesting, threshing, separating and cleaning losses to be 0.3% (Govindaraj et al., 2017; Benaseer et al., 2018).

According to the direction of the grain flow relative to the axis of the threshing unit, it could be classified into axial-flow and tangential-flow (Fu et al., 2018). Recently, the axial-flow rice combine harvester is more dominant and widely used (Mairghany et al., 2018; Srison et al., 2016). In the axial flow combine harvester, the crop moves spirally between the threshing drum and

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concave for several complete turns. Crop is thus threshed for longer duration by repeated impact of threshing pegs. This principle permits multi-stage threshing and grain straw separation, resulting in a higher output and cleaning efficiency in comparison with the tangential threshing mechanism (Sinha et al., 2014; Ahorbo, 2016; Valge et al., 2017; Fu et al., 2018; Mairghany et al., 2018; Abdeen et al., 2021).

The grain loss and damage are always the major evaluation of the threshing performance. So, the combine harvester manufacturers applied different techniques to enhance threshing performance. One of these techniques is modifying the threshing unit to comprise a housing in which is situated primary and secondary threshing drums. The main drum extracts the grains from the panicles, while, the secondary drum extracts the remained un-threshed grains.

The most frequent breakdown has been occuring is the crop blockage inside the threshing chamber. It is attributed to the wearing of the secondary drum forks and bearing. This problem lowers the combine harvester productivity and field efficiency and increases the total grain losses.

This study aimed to modify the combine harvester rice threshing device for reducing the crop blockage to overcome the complaints of the increasing of the total grain losses and to improve the combine harvester field capacity.

2 Material and methods

To fulfill the study objective, during 2018 summer season, a field experiment of 2.10 ha was carried out at Abo-Seifah Village, El-Delengat Center, El-Beheira Governorate, Egypt that located at 30.8480986 latitude and 30.3435506 longitude.

According to Black et al. (1965), the soil texture was classified as clay with soil particles distribution of 1.30% fine sand, 18.50% coarse sand, 21.20% silt and 59.00% clay.

2.1 Agricultural practices

Seed bed preparation:

The soil was prepared using a chisel plough in two perpendicular directions at 0.20 m depth and the secondary tillage was carried out using a tandem disc harrow. The soil precision land leveling was conducted at 0% slope using the hydraulic land leveler that is accompanied with laser control equipment.

Planting:

Sakha 101 rice variety selected seeds were mechanically drilled with a rate of 140 kg ha^{-1}.

Harvest and threshing:

At the physiological maturity stage, rice yield components were found to be 0.90 m plant height, 115 grains/panicle, 520 panicles/m^2, 22 panicles/hill, 3.4 g mature grains mass/panicle and 29 g 1000 grains mass, while, the grain yield was 4.50 ton/fed. Then, the rice plants were harvested and threshed using a self-propelled rice combine harvester. The crop was harvested at three times within an interval of 10 days to maintain different grain moisture content levels, which were found to be 20%, 23% and 25% (d.b.) as outlined by ASAE (1992).

Table 1 Combine harvester specifications

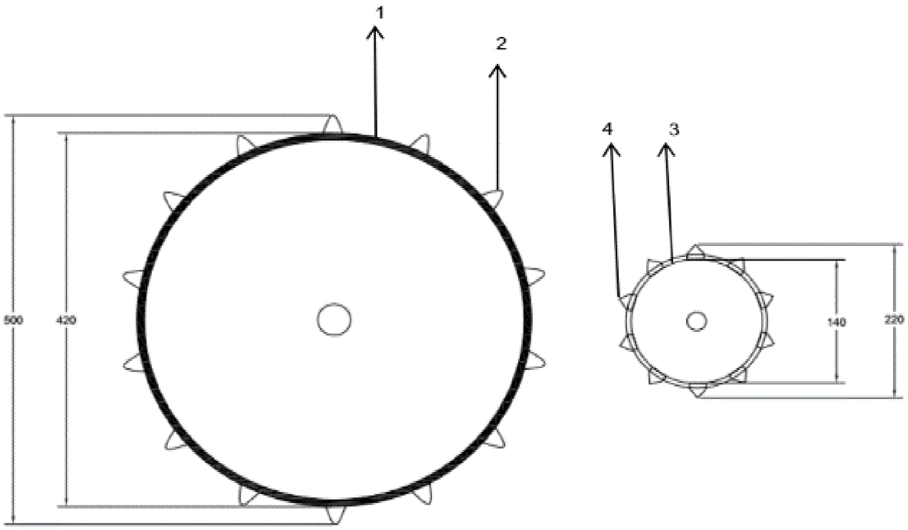
Feature	Specification	Feature	Specification
Trade mark	Yanmar	Model	CA-385 EG
Manufacture	Japan	Type	Head-feeding
Overall dimensions:		Cutting device:	
Length, m	4.063	Cutting width, m	1.40
Width, m	1.904	Cutting adjusted	Hydraulically
Height, m	2.160		
Mass, kg	1979	Traction device	Rubber crawler
Engine type	Vertical, diesel, 3 cylinder, 4-cycledieses and water cooling	Engine out-put power, kW	28.50 at 2800 rpm
Main threshing drum:		Secondary threshing drum:	
Diameter, m	0.42	Diameter, m	0.14
Length, m	1.70	Length, m	0.90
Threshing unit type	Shaking sieves and fans	Threshing principle	Tangential axial

According to Yanmar workshop manual (2007), the combine harvester was used at the optimum operational conditions of 3.50 km h^{-1} forward speed, 520 rpm peripheral speed for both main (11.43 m s^{-1}) and secondary (34.29 m s^{-1}) threshing drums, 0.006 mm concave clearance and 0.25 m^{3} s^{-1} air flow rate. The used combine harvester is specified at Table 1.

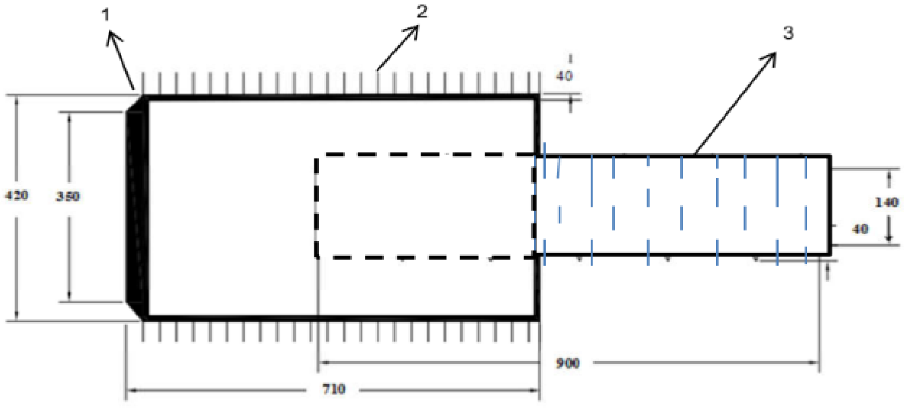
All other agricultural practices were applied as the recommendations of Rice technical recommendations (2016).

2.2 Modification of secondary threshing drum

As shown in Figure 1, around the drum periphery, there are 58 forks are installed with an alternative distribution at 7 rows. Figure 2 indicates a fork view.



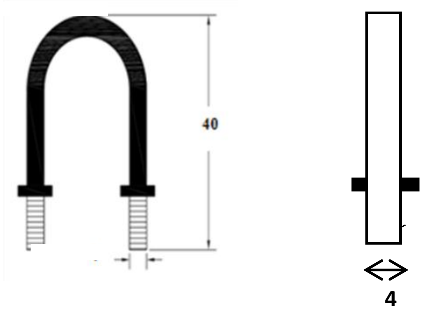
(a) Ele.Dimensions by mm



(b) Side view

1. Main cylinder drum 2. Fork 3. Secondary cylinder drum 4. Fork

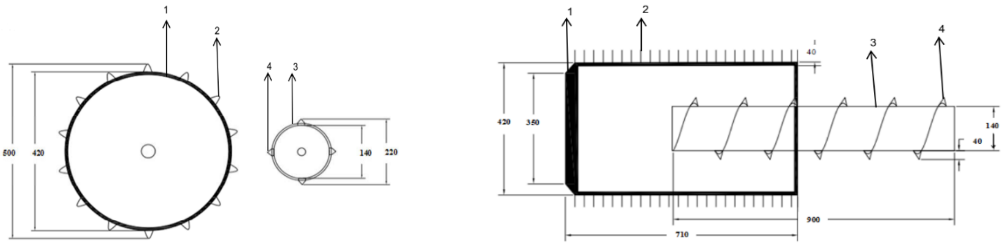
Figure 1 Rice combine harvester threshing device



Elev. Side view

Figure 2 Secondary threshing drum fork

As indicated in Figure 3, the secondary threshing drum was modified by replacing the forks with 28 steel iron knife blades of 0.03 m width and 0.04 height. The blades were installed with a spiral distribution in a steel strip of 1.50 m length and 0.002 thickness. The strip was wrapped around the drum in using a solid tape. Figure 4 shows the knife blade view.

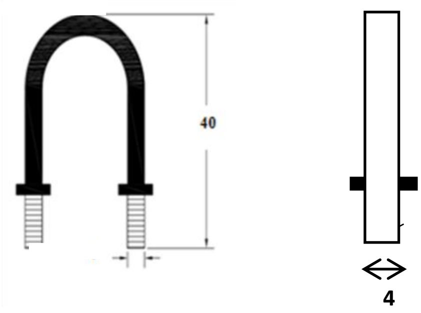


Elev. Dimensions by mm.

Side view

1. Main cylinder drum 2. Fork 3. Secondary cylinder drum 4. Knife blade

Figure 3 Combine harvester threshing device after modification



Elev.

Side view

Figure 4: Secondary threshing drum knife blade.

Treatments and statistic design:

During the present study, the combine harvester was evaluated using the secondary drum, comparing with the original drum. The following treatments were tested:

Rice grain moisture content: it included the levels of 20%, 23% and 25% (d.b.).

Operational time: it included the levels of 50, 100, 150 and 200 hrs.

The experiment was established and statistically designed as a factorial completely randomized blocks design with three replications.

Measurements:

Wearing rate:

As cited by Archard (1980), the secondary drum forks and blades wearing rate is determined as follows:

$$wearing\ rate = \frac{mass\ loss,\ g}{operating\ time,\ h}\ x\ 100,\ \%,g/h \quad (1)$$

Combine harvester performance:

According to Kepner et al. (1982), the combine harvester performance is estimated as follows:

Actual field capacity (AFC):

$$AFC = \frac{1}{ATT}\ \text{fed h}^{-1} \quad (2)$$

Where: ATT is the actual total time required for threshing one fed, hrs.

Machinery field efficiency (ηf):

$$\eta_f = \frac{AFC}{TFC}\ x\ 100\% \quad (3)$$

Where: TFC is the theoretical field capacity, fed h^{-1}.

Rice grain threshing measurements:

According to FAO (1994), rice grain threshing measurements are estimated as follows:

Visible damaged grains:

$$visible\ damaged\ grains = \frac{visible\ damaged\ grains\ mass,\ g}{total\ grains\ mass,\ g} \times 100\ ,\% \quad (4)$$

Un-threshed grains:

$$un\text{-}threshed\ grains = \frac{un\text{-}threshed\ grains\ mass,\ g}{total\ grains\ mass,\ g}\ x\ 100,\ \% \quad (5)$$

Total losses:

$$total\ grains\ losses = \frac{visible\ damaged\ grains\ mass\ + un\text{-}threshed\ grains\ mass, g}{total\ grains\ mass, g} x\ 100, \% \quad (6)$$

Threshing efficiency:

$$threshing\ efficiency = \frac{threshed\ grains\ mass, g}{total\ grains\ mass, g} x\ 100, \% \quad (7)$$

Statistical Analysis:

Microsoft Excel 2019 computer software is used to employ the analysis of variance and the LSD tests for rice grains threshing efficiency data.

Regression and Correlation Analysis:

Microsoft Excel 2019 computer software is used to carry out the multiple regression and correlation analysis to represent the relation between rice threshing efficiency and both rice grain moisture content and operating time.

3 Results and Discussion

Wearing rate:

Figure 5 exhibits that the lower wearing rate values of secondary threshing drum forks and knife blades were 0.30 and 0.20 g h^{-1}, respectively. These values were obtained at 25% rice grain moisture content and 50 h operating time. The figure shows that all knife blade wearing rate values were lower than the corresponding values of the forks. This observation is due to the lower friction between the knife blade surface and the crop as a function of the blade larger contact area, diminishing the friction force against the threshed crop, comparing with that of the fork. The figure revealed the inversely effect of rice grain moisture content on both blade and fork wearing rate. This finding may be attributed to the increased grain deformation and surface area with the moisture content, resulting in lowering the grain friction coefficient. In addition, it is logic that the operating time affected directly the wearing rate. It refers to the reduction in the contact area between the either fork of the blade and the threshed crop with the operating time, leading to the increased mass loss of fork and blade.

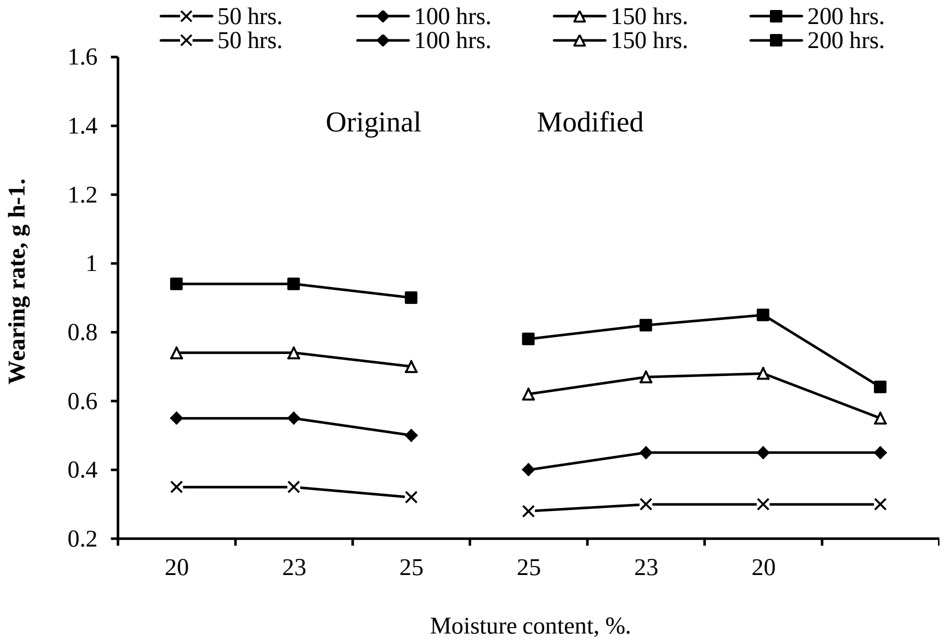


Figure 5 Effect of rice grain moisture content and on secondary threshing drum wearing rate under different operating time levels.

Combine harvester performance:

Table 2 indicates that the combine harvester field capacity values using the modified secondary drum were higher than the corresponding values using the original drum. Also, the table shows the slight increase of the combine harvester field capacity with the grain moisture content. Meanwhile, the combine harvester field capacity related reversibly with the operating time.

As presented in Table 2, the combine harvester field efficiency values using the modified drum were higher than the corresponding values using the original drum. In addition, the grain moisture content did not affect the combine harvester field efficiency. Furthermore, there was a drop in the combine harvester field efficiency with the operating time.

The previous results imply that the combine harvester performance was influenced by the secondary drum forks and blades wearing rate. The higher wearing rate increased the crop lockage inside the threshing chamber, resulting in more wasting time.

Table 2 Effect of rice grain moisture content on combine harvester performance under different operating time levels.

Secondary drum		Original			Modified		
Moisture content, %		20	23	25	20	23	25
Field capacity, fed h^{-1}	50 hrs.	0.89	0.90	0.90	0.92	0.93	0.93
	100 hrs.	0.87	0.88	0.88	0.89	0.90	0.90
	150 hrs.	0.85	0.85	0.86	0.87	0.87	0.88
	200 hrs.	0.82	0.83	0.83	0.85	0.86	0.86
Field efficiency, %	50 hrs.	86	86	86	91	91	91
	100 hrs.	83	83	83	89	89	89
	150 hrs.	81	81	81	86	86	86
	200 hrs.	78	78	78	82	82	82

Rice grain losses:

Visible damaged grains:

Data presented in Figure 6 show that the lower visible damaged grain values of 0.31% and 0.25% were recorded using original and modified secondary drums, respectively. This finding may be explained that the fork higher wearing rate achieved a rigid surface of higher friction resistance. Consequently, the impact of fork against grains increased the grain damage. As demonstrated in Figure 6, there is a reversible relation between damaged grains and grain moisture content. It may be illustrated that at lower grain moisture content levels, the grain has lower strength against impact force of either fork or blade, leading to higher damaged grains values. The figure declares that the damaged grains are directly proportional to the operating time. This result is due to the positive relation between either fork or blade wearing rate and the operating time that fulfilled higher damaged grain values.

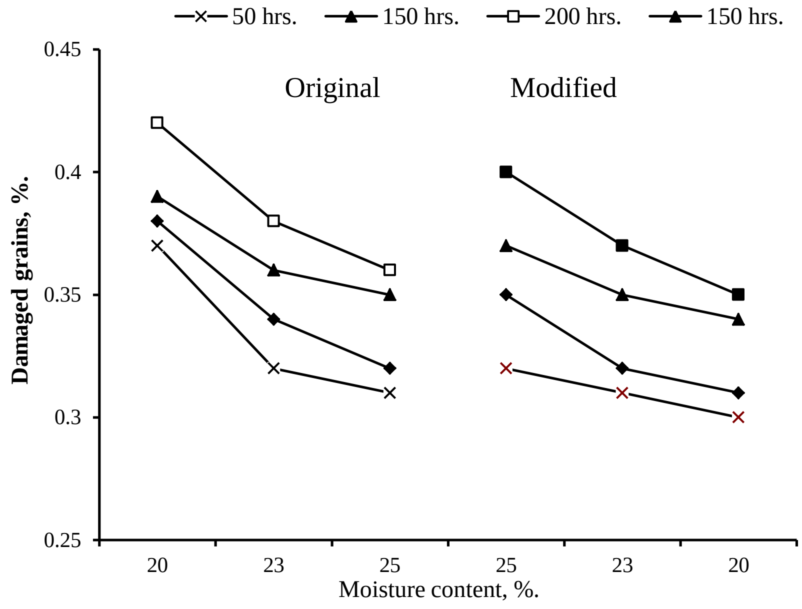


Figure 6 Effect of rice grain moisture content on visible damaged grains under different operating time levels.

Un-threshed grains:

As shown in Figure 7, the original and modified secondary drums recorded the lower un-threshed grain values of 0.32% and 0.28%, respectively. This finding may be construed that the spiral distribution of secondary drum blades facilitated the grain separation more than the forks alternative distribution. The figure shows the direct proportional of un-threshed grains to grain moisture content. It is due to the positive effect of grain moisture content on grain elasticity which allows the easy motion of threshed material at lower moisture content inside threshing chamber without completing the threshing operation. Meanwhile, the un-threshed grain losses increased with the operating time. As the operating time increased, the crop lockage increased due to the proportion of forks and blades wearing rate with the operating time.

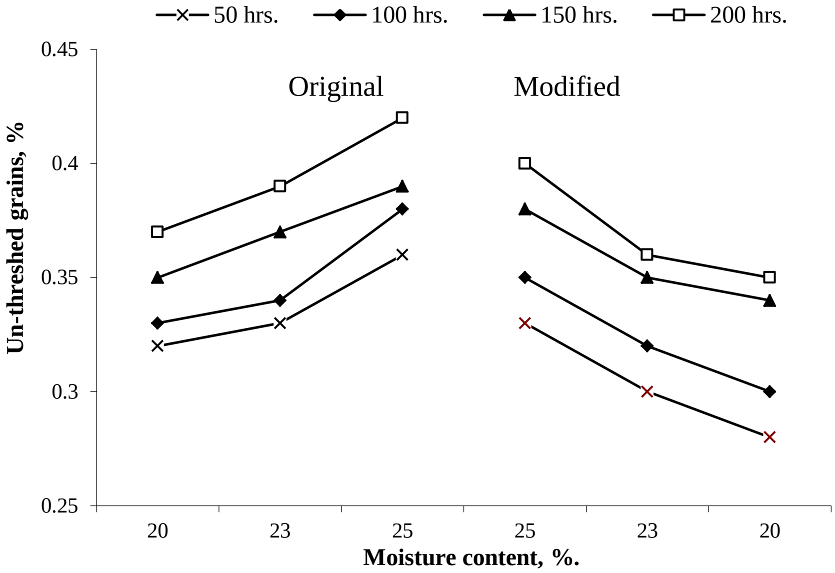


Figure 7 Effect of rice grain moisture content on un-threshed grains under different operating time levels

Total grain losses:

Data presented in Figure 8 show that lower values of total grain losses of 0.65% and 0.61% were recorded at 23% grain moisture content and 50 hrs. operating time using original and modified drums, respectively. This trend may be illustrated that the total grain losses are considered as the result of bot damaged and un-threshed grains. So, the modified secondary drum accomplished lower total grain losses than the original drum. Whilst, the grain moisture content affected the total grain losses according to the following order: 23%< 25%< 20%. This finding is a result of both reversible and positive effects of grain moisture content on damaged and un-threshed grains, respectively. In addition, both damaged and un-threshed grains were proportional to the operating time.

Threshing efficiency:

Data presented in Tables 3 and 4 indicated the significant effect of grain moisture content, operating time and interaction of grain moisture content and operating time on rice threshing efficiency using both original and secondary drums.

Table 3 Analysis of variance of threshing efficiency using the original secondary drum.

S.V.	S.S.	D.F.	M.S.	F	P-value	F crit
A	0.951667	2	0.475833	22.24675	3.43E-06	3.402826
B	1.525278	3	0.508426	23.77056	2.29E-07	3.008787
A x B	0.097222	6	0.016204	0.757576	0.609924	2.508189
Within	0.513333	24	0.021389			
Total	3.0875	35				

Note: A: rice grain moisture content, B: combine harvester operating time.

Table 4 Analysis of variance of threshing efficiency using the modified secondary drum.

S.V.	SS	df	MS	F	P-value	F crit
A	0.221667	2	0.110833	14.77778	6.56E-05	3.402826
B	1.126667	3	0.375556	50.07407	1.76E-10	3.008787
A x B	0.031667	6	0.005278	0.703704	0.64953	2.508189
Within	0.18	24	0.0075			
Total	1.56	35				

Note: A: rice grain moisture content, B: combine harvester operating time.

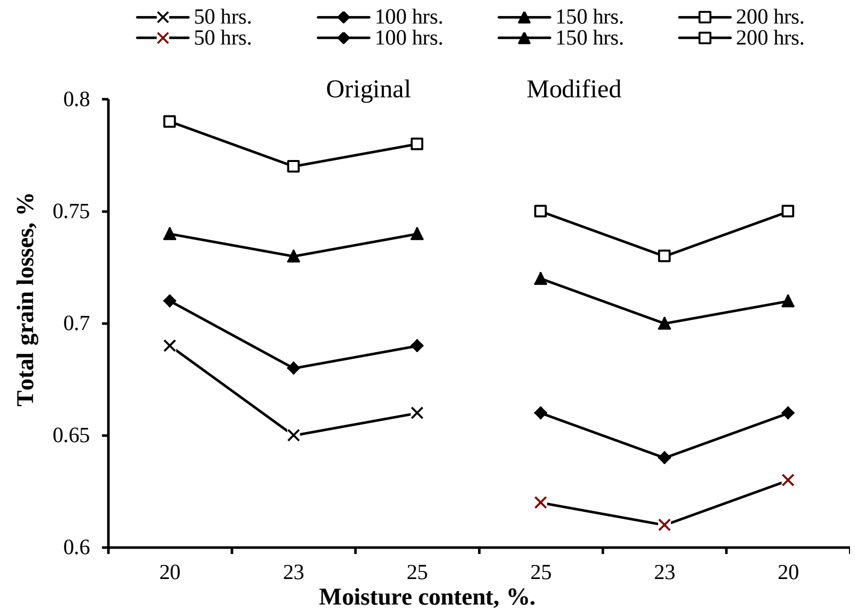


Figure 8 Effect of rice grain moisture content on total grain losses under different operating time levels.

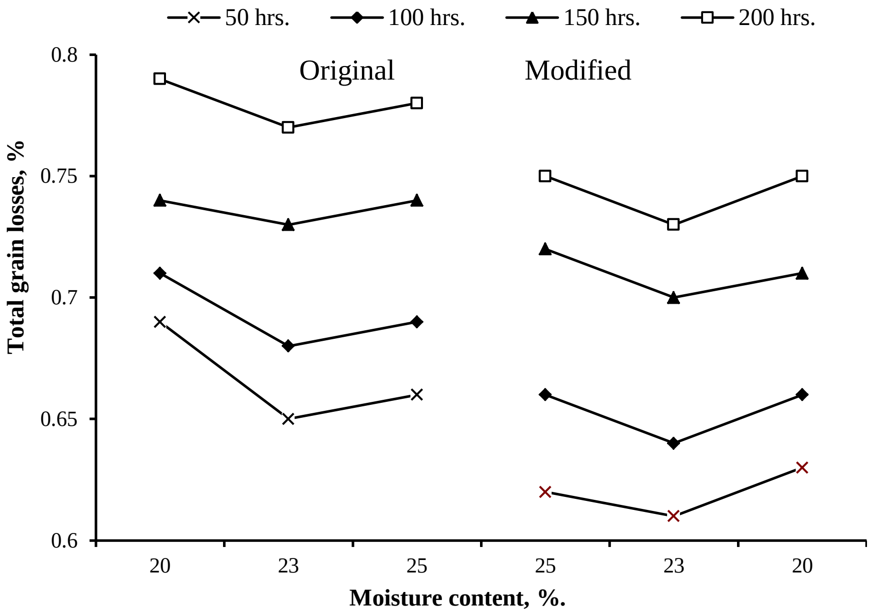


Figure 9 Effect of rice grain moisture content on threshing efficiency under different operating time levels.

The regression and correlation analysis revealed that there is a highly positive correlation between rice threshing efficiency (y) and both grain moisture content (x^1) and operating time (x^2) as follows:

Original drum: $y = 0.041239\ x^1 + 0.000278\ x^2$
$R^2 = 0.992052$

Modified drum: $y = 0.04134\ x^1 + 0.000266\ x^2$
$R^2 = 0.9919320.992052$

Figure 9 shows that higher threshing efficiency values of 98% and 98.2% were obtained at 23% grain moisture content and 50 hrs. operating time using original and modified drums, respectively. This finding may be explained that the threshing efficiency is a reversable function of the total grain losses.

4 Conclusion

The modification of the rice combine harvester secondary drum accomplished lower values of blades wearing rat. Consequently, this modification achieved higher combine harvester performance, lower grain losses and higher threshing efficiency. The grain moisture content and the operating time affected significantly rice threshing efficiency. It is recommended to operate the combine harvester using the modified threshing drum, especially at 23% grain moisture content and 50 hrs. operating time.

References

Abdeen, M. A., A. E. Salem and G. Zhang 2021. Longitudinal axial flow rice thresher performance optimization using the Taguchi technique. *Agriculture*, 11(2): 88.

Ahorbo, G. K. 2016. Design of a throw-in axial flow rice thresher fitted with peg and screw threshing mechanism. *International Journal of Science and Technology Research*, 5(7): 170-173.

Alex, Q. 2016. Performance evaluation of a motorized mini-rice thresher. B.S. thesis, Agric. Eng. Dept., Agric. Mech. Eng. Fac., Eng. College, Kwame Nkrumah Univ. of Sci. and Technol., Kumasi, Ghana.

Alizadeh, M. R., and I. Bagheri. 2013. Field performance evaluation of different rice threshing methods. *International Journal of Natural and Engineering Sciences*, 3(3): 155-159.

Archard, J. F. 1980. Wear theory and mechanisms. In *Wear Control Handbook*, ed. M. B. Peterson, and W. O. Winer, ch., 35-80. New York, USA: ASME.

ASAE 1992. Standard s. 2964. cubes, pellet and crumbles definitions and methods for determining density, durability and moisture content: 384.

Benaseer, S., P. Masilamani, V. A. Albert, M. Govindaraj, P. Selvaraju, and M. Bhaskaran. 2018. Impact of harvesting and threshing methods on seed quality-A review. *Agricultural Reviews*, 39(3): 183-192.

Black, C. A., D. D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark. 1965. *Methods of Soil Analysis: Part 1, Physical and Mineralogical Properties, Including Statistics Of Measurements and Sampling*. Madison Wison Wisconsin, USA: American Society of Agronomy Inc.

FAO. 1994. Testing an evaluation of Agricultural Machinery and Equipment. Principles and Pratices. Food and Agricultural Organization (FAO) Agricultural Services Bulletin No. 110. Rome, Italy: FAO.

Fu, J., Z . Chen, L. Han, and L. Ren. 2018. Review of grain threshing theory and technology. *International Journal of Agricultural and Biological Engineering*, 11(3): 12–20.

Govindaraj, M., P. Masilamani, D. Asokan, P. Rajkumar, and P. Selvaraju. 2017. Effect of different harvesting and threshing methods on harvest losses and seed quality of rice varieties. *International Journal of Current Microbiology and Applied Sciences*, 6(9): 1510-1520.

IRRI. 2015. Manual threshing. Available at: http://www.knowledgebank.irri.org/step-bystep-production/postharvest/harvesting/harvestingoperations/threshing/manual-threshing. Accessed 11 November 2015.

Kepner, R. A., R. Bainer, and E. L. Barger. 1982. *Principles of Farm Machinery*. 4th ed. John Wiley and Sons, Inc., New Jersey, USA.

Mairghany, M., A. Yahya, N. M. Adam, A. S. M. Su, and S. Elsoragaby. 2018. Quality of performance and grain losses of two type of rice combine harvesters. *Agricultural Research and Technology: Open Access Journal*, 19 (2): 55-65.

Rice technical recommendations 2016. Central Administration for Agricultural Extension. Pamphlet No. 1363.: Rice Research and Training Center, Egypt.

Singh, M. K., S. P. Singh, H. L. Kushwaha, M. K. Singh and U. Ekka. 2020. Combine harvester: Opportunities and prospects as resource conservation technology. RASSA Journal of Science for Society, 2(1): 53-57.

Sinha, J. P., G. S. Manes, A. Dixit, A. Singh, M. Singh, and B. P. Singh. 2014. Performance evaluation of axial flow and tangential axial flow threshing system for basmati rice (*Oryza Sativa*). *International Journal of Research In Agriculture and Forestry*, 1(2): 44-49.

Srison, W., S. Chuan-Udom, and K. Saengprachatanarak. 2016. Effects of operating factors for an axial-flow corn shelling unit on losses and power consumption. *Agriculture and Natural Resources*, 50(5): 421–425.

Valge, A. M., M. I. Lipovskiy, and A. N. Perekopskiy. 2017. Multicriteria optimization of the combine harvester thresher threshing-separating device parameters. *Bulletin of the Russian Agricultural Science*, 3: 18-21.

Yanmar Workshop manual. 2007. Parts Catalog. Combine Harvester CA 48 e x. Yanmar Co., Ltd (unpublished).