

**DESIGN, DEVELOPMENT AND EVALUATION OF
THRESHER - DRYER - DEHUSKER
FOR ON-FARM BROWN RICE PRODUCTION**

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**CENTRE FOR RURAL DEVELOPMENT AND TECHNOLOGY
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FOR ON-FARM BROWN RICE PRODUCTION**

by

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CERTIFICATE

This is to certify that the thesis entitled “**Design, development and evaluation of thresher–dryer–dehusker for on-farm brown rice production**” being submitted by **Mr. MUKESH JAIN** to the Indian Institute of Technology Delhi for the award of “**Doctor of Philosophy**” is a record of bonafide research work carried out by him under our guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology Delhi. The research report and results presented in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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ABSTRACT

Rice is one of the main staple foods of the world, and people prefer to consume white rice, in spite of the fact that brown rice is rich in nutrition. One of the main reasons, for non-adoption of brown rice, is its higher cost. Power operated threshers are generally used to detach the grains from the panicles of the paddy crop and the paddy grains are sold in the market at a very low price. The detached raw paddy grains are further processed at modern rice mills to remove the husk and produce brown rice and white rice of commercial quality, thus major profit is earned by rice millers. Looking into the importance of brown rice and fore-seeing the increase in demand of brown rice, a need of a machinery fulfilling above purpose was felt which can directly give output in the form of good quality brown rice at lower cost.

Based on physico-mechanical properties of four paddy varieties, the design concept of thresher for brown rice production was evolved which consisted of co-axial split-rotor thresher of length 840 mm and diameter 400 mm having 21 spike teeth for paddy threshing, which is specially suited for high moisture paddy; and two rotary dryers (\varnothing 430 mm and length 3600 mm) fitted with 18 nos. of ceramic infrared (IR) heaters (650 W) along the central axis of rotary dryers was designed. The dryers were designed to run at different rpm (6, 7 and 8 rpm) and at different inclination (4° , 5° and 6°). Recently, IR radiation is being used for drying agricultural products for achieving fast and uniform heating of the grains for quick removal of moisture. A rubber sheller unit for brown rice production and conical abrasive polisher (as an optional feature) was added to produce white rice. Thus, a tractor operated paddy thresher-cum-dryer-cum-dehusker-cum-polisher having output capacity of 150 kg/h of rice was developed.

The developed machine was evaluated for two non-basmati paddy varieties *i.e.*, Pusa-44 and PR-114 and two basmati paddy varieties *i.e.*, Pusa-1121 and Pusa-1509. The moisture content of the grain at the time of threshing varied from 18 to 20% (wb). The choice of opting co-axial split threshing cylinder had proved to be successful in achieving almost 100% threshing efficiency and more than 98% cleaning efficiency, even at higher moisture content of paddy crop. The percentage of broken and blown paddy grains was 0.32 and 0.15, respectively. The optimum feed rate was found to be 150 kg/h of raw paddy. Optimum retention time of 2.5 minutes was obtained at 5° slope and 7 rpm of rotary dryer. On an average, the moisture content of the paddy grains was reduced by $\sim 3\%$ in the first dryer and another $\sim 2.5\%$ in the second dryer. Thus, the moisture content which was 18 to 20% (wb) at the time of threshing was reduced to about 13 to 14%.

Dehusking efficiency of all the varieties was more than 98.5% except Pusa-1509 in which it was only 95%, being an awn variety. The brown rice recovery was found to be 71 and 75% in basmati and non-basmati varieties, respectively. Average head brown rice recovery in the

basmati and non-basmati varieties was approximately 35.75 and 56.40 kg per 100 kg of paddy, respectively. Percentage of head brown rice recovery was 50.28 and 75.20 in basmati and non-basmati varieties, respectively.

Single polishing of the brown rice was performed with the conical abrasive polisher which is provided in the machine as an optional feature. The average white rice recovery (white rice milling recovery) was found to be 61.70 and 65.25 kg per 100 kg of raw paddy in basmati and non-basmati varieties, respectively. Average head white rice recovery in the basmati and non-basmati varieties was 30.35 and 48.25 kg per 100 kg of paddy, respectively.

The study of quality characteristics (fat, carbohydrates, protein, ash, crude fiber and micronutrients) of brown rice and single polished rice revealed that there was no difference in the quality produced by the developed machine and the rice mill. However, in case of polished rice, the percentage reduction in protein, fat, ash and crude fibre was found to be 13.4, 48.4, 41.6 and 73.8 as compared to brown rice. The vitamins like thiamine (B₁), riboflavin (B₂), niacin (B₃), pantothenic acid (B₅), pyridoxine (B₆) and biotin (B₇) in the polished rice were lesser by 91.6, 18.7, 47.9, 9.8, 68.7 and 55.6%, respectively as compared to brown rice. Thus, it can also be concluded that consuming brown rice is more beneficial for human health as most of the nutrients gets eliminated in polished rice.

Techno-economic analysis of the newly developed tractor operated paddy thresher-cum-dryer-cum-dehusker revealed that by using this machine, the reduction in the cost of basmati brown rice and polished rice has been found to be 31 and 29%, respectively, as compared to the rice mill. Similarly, the reduction in the cost of non-basmati brown rice and polished rice has been found to be 25 and 24%, respectively. The machinery owner can earn a profit of Rs.1,35,000 per annum, if the machine is operated for 450 hours in a year. The Break Even Point (B.E.P.), Pay back period and Return on Investment (ROI) were found to be 284 hours, 4.44 years and 9.64%, respectively.

Overall, it is inferred that by adopting newly developed paddy processing system farmers will have an option to produce brown rice at their farm itself at a cheaper cost, consume it and remain healthy. Moreover, since the machine has an optional feature of having polisher, the machine can also be used for producing polished rice at lower price. In other words, the major profit which is being earned by middle men can be avoided and farmers can get better price for the same. In fact, it has been a journey of paradigm shift for achieving food security coupled with human health.

साराँश

चावल दुनिया के प्रमुख मुख्य खाद्य पदार्थों में से एक है। लोग इस तथ्य के जानने के बावजूद कि ब्राउन चावल पोषण से भरपूर होते हैं, सफेद चावल का सेवन करना पसंद करते हैं। ब्राउन चावल को न अपनाने के मुख्य कारणों में से एक – इसकी अधिक कीमत है। धान की फसल के बालियों से अनाज को अलग करने के लिए आमतौर पर ट्रैक्टर से चलने वाले थ्रेशरों का उपयोग किया जाता है और धान के दानों को बहुत सस्ती दर पर बाजार में बेचा जाता है। अलग किए गए धान के दानों का आधुनिक चावल मिलों में आगे प्रसंस्करण किया जाता है, और वाणिज्यिक गुणवत्ता के ब्राउन चावल एवं सफेद चावल का उत्पादन किया जाता है, और इस प्रकार से, प्रमुख लाभ चावल मिल मालिक अर्जित करते हैं। ब्राउन राईस के महत्व एवं आने वाले समय में इसकी मांग में वृद्धि को देखते हुए, एक मशीनरी की आवश्यकता महसूस की गई जो किसान को उसके फार्म पर ही सीधे सस्ती कीमत पर ब्राउन चावल के रूप में उत्पादन दे सकती है।

चार धान की किस्मों की भौतिक-यांत्रिक गुणों के आधार पर, ब्राउन राईस उत्पादन के लिए थ्रेशर की डिजाइन अवधारणा विकसित की गई, जिसमें सह-अक्षीय विभाजन-रोटर थ्रेशर (लंबाई 840 मिमी और व्यास 400 मिमी) शामिल थे जिसमें धान थ्रेशिंग के लिए 21 दाँतों (स्पाइक) वाला थ्रेशिंग सिलेंडर डिजाइन किया गया, जो विशेष रूप से उच्च नमी वाले धान के लिए अनुकूल है। दो-रोटरी ड्रायर को धान सुखाने के लिए (430 मि.मी. व्यास 3600 मि.मी. लम्बाई) डिजाइन किया गया जिसके अन्दर 18 सेरेमिक इन्फ्रारेड हीटर (IR) (650 वाट) का इस्तेमाल किया गया। रोटरी ड्रायर विभिन्न आरपीएम (6,7 और 8) तथा अलग-अलग झुकाव (4, 5 और 6 डिग्री) पर चलाने के लिए डिजाइन किया गया था। आजकल इन्फ्रारेड (IR) विकिरण का उपयोग कृषि उत्पादों को सुखाने के लिए एवं नमी के त्वरित निष्कासन के लिए और एक-समान ताप को प्राप्त करने के लिए इस्तेमाल किया जा रहा है। आई आर (IR) विकिरण की उच्च-ताप दर और \dot{A} र्जा दक्षता, पारंपरिक सुखाने के तरीकों से अधिक है। ब्राउन चावल के उत्पादन के लिए रबर शैल्लर इकाई को जोड़ा गया है। इसके अतिरिक्त सफेद चावल के उत्पादन के लिए (एक वैकल्पिक अवयव के रूप में) अलग शक्वाकार अपघर्षक पॉलिशर का भी इस्तेमाल किया गया है। इस प्रकार, एक ट्रैक्टर संचालित धान थ्रेशर-ड्रायर-डिहस्कर-पॉलिशर मशीन (150 किलोग्राम प्रति घण्टा के चावल उत्पादन दर) को विकसित किया गया।

विकसित मशीन का मुल्यांकन दो गैर बासमती धान की किस्मों अर्थात् पूसा-44 और PR-114, और दो बासमती धान की किस्मों यानी पूसा-1121 और पूसा-1509 में किया गया। थ्रेशिंग के समय अनाज की नमी 18 से 20 प्रतिशत (wb) होती है। उच्च नमी वाली धान की फसल में सह-अक्षीय विभाजन थ्रेशिंग सिलेंडर चुनने का विकल्प, लगभग 100% थ्रेशिंग दक्षता और 98% से अधिक सफाई दक्षता प्राप्त करने में सफल साबित हुआ। टुटे चावल एवं हवा के साथ उड़ने वाले दाने क्रमशः 0.32 और 0.15 प्रतिशत थे। थ्रेशर का अनुकूलतम उत्पादन दर 150 किलोग्राम प्रतिघंटा पाई गई। अनुकूलतम धान का प्रतिधारण समय 2.5 मिनट, रोटरी ड्रायर के 5 डिग्री ढलान और 7 आरपीएम पर प्राप्त किया गया। धान के दानों की नमी पहले ड्रायर में औसतन लगभग 3% और दूसरे ड्रायर में 2.5% कम हुई है। इस प्रकार थ्रेशिंग के समय नमी की मात्रा 18-20% (wb) से घटकर 13-14% रह गई।

सभी किस्मों की डीहस्किंग दक्षता 98.5% से अधिक थी परन्तु पूसा-1509 में यह केवल 95% थी, जोकि एक बालों वाली किस्म थी। ब्राउन चावल की रिकवरी बासमती और गैर-बासमती किस्मों में क्रमशः 71 और 75% पाई गई। बासमती और गैर-बासमती किस्मों में औसत हैड ब्राउन राईस रिकवरी क्रमशः 35.75 और 56.40 किलोग्राम प्रति 100 किलोग्राम धान थी। बासमती और गैर-बासमती किस्मों में हैड ब्राउन राईस रिकवरी क्रमशः 50.28 और 75.20 प्रतिशत थी। ब्राउन राईस का एकल पॉलिशिंग, शंकुधारी अपघर्षक पॉलिशर के उपयोग से किया गया था जो कि एक वैकल्पिक विशेषता

के रूप में मशीन में प्रदान किया गया है। बासमती और गैर-बासमती किस्मों में औसत सफेद चावल रिकवरी (सफेद चावल मिलिंग रिकवरी) क्रमशः 61.70 और 65.25 किलोग्राम प्रति 100 किलो धान की पाई गई। बासमती और गैर-बासमती किस्मों में औसत हैड सफेद चावल की रिकवरी क्रमशः 30.35 और 48.25 किलोग्राम प्रति किलो धान थी।

ब्राउन चावल और एकल पॉलिश वाले चावल (सफेद चावल) की गुणवत्ता (वसा, कार्बोहाइड्रेट, प्रोटीन, राख, आहार फाइबर और सूक्ष्म पोषक तत्व) के अध्ययन से पता चला है कि विकसित मशीन और चावल मिल द्वारा उत्पादित चावल की गुणवत्ता में कोई अंतर नहीं था। हालांकि, पॉलिश चावल में, ब्राउन चावल की तुलना में प्रोटीन, वसा, राख और आहार फाइबर में 13.4, 48.4, 41.6 और 73.8 प्रतिशत कमी पाई गई। पॉलिश किए गए चावल में थाइमिन (B₁), राइबोफ्लेविन (B₂), नियासिन (B₃), पैंटोथैनिक एसिड (B₅), पायरोडॉक्सिन (B₆) और बायोटिन (B₇) जैसे विटामिन क्रमशः 91.6, 18.7, 47.9, 9.8, 68.7 और 55.6 प्रतिशत कम थे। इस प्रकार यह भी निष्कर्ष निकाला जा सकता है कि पॉलिश किए हुए चावल में अधिकांश पोषक तत्व नष्ट हो जाते हैं।

नई विकसित मशीन ट्रेक्टर-चालित धान थ्रेशर-झायर-डिहस्कर के तकनीकी-आर्थिक विश्लेषण से स्पष्ट हुआ कि इस सिस्टम का उपयोग करके चावल मिल की तुलना में बासमती ब्राउन चावल और सफेद चावल की लागत में क्रमशः 31 और 29 प्रतिशत की कमी पाई गई है। इसी प्रकार, गैर-बासमती ब्राउन चावल और पॉलिश चावल की लागत में क्रमशः 25 और 24 प्रतिशत की कमी पाई गई। यदि कथित मशीन को एक वर्ष में 450 घंटे के लिए संचालित किया जाता है, तो मशीन मालिक प्रति वर्ष 1,35,000 रुपये का लाभ कमा सकता है। ब्रेक ईवन प्वाइंट (B.E.P.), पे-बैक पीरियड और रिटर्न ऑन इन्वेस्टमेंट (ROI) क्रमशः 284 घंटों, 4.44 वर्ष और 9.64 प्रतिशत पाए गए।

कुल मिलाकर यह निष्कर्ष निकाला जाता है कि ट्रेक्टर चालित धान प्रसंस्करण सिस्टम को अपनाने से किसानों के पास यह विकल्प होगा कि वे सस्ते दाम पर अपने फार्म पर ही ब्राउन चावल का उत्पादन कर सकते हैं, और सेवन करके स्वस्थ रह सकते हैं। इसके अलावा चूंकि मशीन में पॉलिशर की एक वैकल्पिक व्यवस्था दी गई है, इसलिए मशीन का उपयोग सस्ती कीमत पर सफेद चावल बनाने के लिए भी किया जा सकता है। दूसरे शब्दों में, बिचौलियों द्वारा अर्जित किए जाने वाले प्रमुख लाभ से बचा जा सकता है और किसानों को इसके लिए बेहतर कीमत मिल सकती है। वास्तव में यह अद्भुत कार्य “चिन्तन में परिवर्तन” की एक शोध यात्रा है, जिसकी उपयोगिता समाज के लिए खाद्य सुरक्षा एवं मानव स्वास्थ्य के रूप में परिलक्षित होगी।

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List of Abbreviations

Abbreviation	Full form
µm	Micrometer or Micron
ANOVA	Analysis of Variance
AOAC	Association of Analytical Communities
ATCC	American Type Culture Collection
db	Dry basis
hp	Horse power
IR	Infrared
IS	Indian Standards
LDPE	Low Density Poly Ethylene
MOG	Material Other than Grain
MS	Mild Steel
NR	Not Reported
Θ	Angle of inclination in degrees
PTO	Power Take Off
R ²	Coefficient of Determination
rpm	Revolutions Per Minute
Rs.	Rupees
RNAM	Regional Network for Agricultural Machinery
S.D	Standard Deviation
SPSS	Statistical Package for the Social Sciences
t	Tonne
wb	Wet basis