Rice Sorter Machine and Processing Line For Red Rice Seeds Elimination

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ABSTRACT

This work aims at determining a new method for sorting pure seeds and red rice seeds. Spectral analysis of pure and red rice seeds has demonstrated that they can be sorted according to their structural properties. The paper suggests using lasers for real-time sorting. An optical sorting method based on using lasers to sort out dockage is described and the working principle of the constructed fiber optic laser sorter is demonstrated. The sorter specifications and its operation within the processing line is shown. Using the sorter within the processing line to sort rice grains of species «Yuzhnyi» and «Austral» has yielded following results: with the portion of shelled red rice seeds of 1.44-2.62% and processing line capacity equal or higher than nominal by 1.57-1.71 kg/sec, the pure grain loss is over 10% and the quantity of red rice seeds is 0.69...1.03%, which does not fit the requirements of state standard of Russian Federation (GOST R 52325-2005, 2006) for the reproductive rice seeds. When the processing line capacity is equal or lower than nominal 0.89-1.41 kg/sec, and the grain loss is less than 10%, the quantity of red rice seeds in the sorted material is not more than 0.37...0.48%, which fits the requirements of state standard of Russian Federation (GOST R 52325-2005, 2006) for the reproductive rice seeds. The suggested sorting method based on determining the seeds structural properties allows to perform real-time effective sorting using fiber optics laser sorter at the capacity equal or lower than nominal (1.41 kg/sec) and the pure grain loss of less than 10%.

Keywords: Optical sorter, fiber optic sorter, rice seeds, red rice seeds.

INTRODUCTION

In recent years, Russia has experienced a growth in rice production for both food and non-food uses. In this regard, the obvious necessity of development of cultivation technologies of reproduction seeds [11,13,19]. To get pure reproduction seeds of high quality, it is necessary to sort out red rice grains, the portion of which in rice paddy grows every year and is now up to 5% for some batches. According to state standard of Russian Federation this portion shall not exceed 0.5% of the reproduction rice seeds used to grow rice for food production. Such requirements result from the fact that rather often a large number of weedy rice seeds gets mixed with the cultivated ones that look similar to them. This problem concerns particularly the cultivated rice mixed with wild red rice that causes Piricularia oryzae - a highly dangerous disease that can lead to crop failure of up to 25 % [3,12].

It is obviously, that the red rice grains cannot be sorted out completely only by standard means (according to their size, aerodynamic properties, weight and other external features). Industrial production of reproduction rice seeds and processing of large rice paddy batches makes the problem of red rice grains separation particularly urgent.

Having studied the existing techniques of separating red rice grains from the cultivated ones, experts from Voronezh State University working together with agricultural machinery specialists of the OAO «Voronezhselmash» suggested to separate red rice grains from the reproduction seeds using fibre optic laser sorting techniques [4,18] . The existing optical sorters usually [15,16,6] sort various grain material according to their external features using LED or luminescent lamps. Using lasers allows sorting the material according to its structural properties, which enables the elimination of red rice grains [5]. The density of the fibre optic laser beam is...
hundreds of times higher than that of the standard optical sorter. Hence, it is possible to illuminate the grains while still in hulls and analyse their structural properties as opposed to analysing only the scattered light data. Besides, it is often necessary to use light beams of various length to eliminate all the dockage, i.e. to use several fibre optic laser sorters with different wavelength [1,2]. We, therefore, suggest using modern fibre optics and laser technologies to separate rice grains from the dockage, and thus promote wider usage of fibre optic laser sorters for sorting out dockage from grain material.

**Materials And Methods**

Objects under examination: pure objects - shelled white-grain rice varieties: «Avstral» and «Yuzhnyi». Defective objects - grains with hidden structural defects: red rice grains. Pure objects sometimes look completely similar to the defective ones. This is true for both «Avstral» and «Yuzhnyi» varieties (Fig.1).

![Fig. 1: Samples («Avstral») of shelled (above) and milled grains (below).](image)

To analyse objects various spectrum analysis methods were applied - reflectance spectroscopy, transmitted light spectroscopy, luminescence spectroscopy [17]. Reflectance, luminescence and transmitted light spectrum, were registered using experimental equipment based upon the fiber optic spectrometer USB4000-VIS-NIR (Ocean Optics). The detailed description of the equipment is given in the following papers [14,1,2].

For separating grains from dockage according to their structural properties a new approach was suggested which performs separation using fibre optic laser sorting techniques as demonstrated in Figure 3.

The approach works as follows. Laser emitters 1 and 2 produce light beams of various wave length, which are then transferred by means of fibre and optical scanning systems 3 into a flat beam light 4. Then from the vibrating feeder bunkers 5 the material comes in a uniform flow to the chutes 6 and 7. After the chutes the grains get into the beam light zone 4. Some of the light transmitted through the grain is registered by a high-speed camera 8. Red rice grains transmit less light than the pure ones, and thus are registered by the camera 8 as darker objects. Then by means of image recognition system the camera passes a certain signal to the pneumatic ejectors 9. The activated air ejectors located opposite the red rice grains, stream the dockage together with some pure grains into the intermediate fraction collector 10, while the pure grains fall into the accepted product collector 11.

![Fig. 3: The working principle of the fibre optic laser sorter](image)
The intermediate fraction helps to reduce the loss of pure seeds. At the next stage the intermediate fraction gets to the vibrating feeder bunkers 12 for re-sorting. From the intermediate fraction the dockage is eliminated as follows. Laser emitters 13 and 14 via the scanning system 15 form a flat beam light 16. Then, from the vibrating feeder bunkers 12 the intermediate fraction is gradually fed to the chutes 17 and 18. After the chutes the grains get into the beam light zone 16. With the help of the camera 19 and pneumatic ejectors 20 the red rice grains get into the rejected material collector 21, while the pure grains together with some of the non-detected red rice grains get into the semi-sorted product collector 22, which then gets to the vibrating feeder bunker 5.

A new fibre optic laser sorting machine was designed based on this principle of sorting out the dockage. The machine is shown in Figure 4.

![Fig. 4: Optical grain sorting machine. Construction diagram. 1 - the raw material bunker, frame, 2 - vibrating chute, 3 - slope chute, return fraction collector, 4 - laser unit, 5 - fibre optics, 6 video modules, 7 - laser beam sweeping system, 8 - light units, 9 - a set of pneumatic ejectors, 10 - rejected material collector, 11 - accepted product collector, 12 - ricochet collector, 13 - intermediate fraction collector, 14 - intermediate fraction vibrating chute, 15 - intermediate fraction slope chute.](image)

The fibre optic laser sorting machine consists of the raw material bunker 1, vibrating chutes 2, slope chutes 3, laser units 4, fibre optics 5, video modules 6, laser beam scanning system 7, light units 8, a set of pneumatic ejectors 9, rejected material collector 10, accepted product collector 11, ricochet collector 12, intermediate fraction collector 13, intermediate fraction vibrating chute 14, and intermediate fraction slope chute 15.

 Specifications of the fibre optic laser grain sorting machine with four feeding chutes are given in Table 1.

![Table 1: Fibre optic laser grain sorting machine specifications](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>SV-4</td>
</tr>
<tr>
<td>The rated capacity of the sorter when the portion of red rice grains is up to 4% of the whole batch, kg/s</td>
<td>1.4</td>
</tr>
<tr>
<td>Type</td>
<td>stationary</td>
</tr>
<tr>
<td>Weight (kg):</td>
<td>1230</td>
</tr>
<tr>
<td>Dimensions (m):</td>
<td></td>
</tr>
<tr>
<td>- length</td>
<td>2.2</td>
</tr>
<tr>
<td>- width</td>
<td>1.45</td>
</tr>
<tr>
<td>- height</td>
<td>2.0</td>
</tr>
<tr>
<td>The number of pneumatic ejectors involved in:</td>
<td></td>
</tr>
<tr>
<td>- the initial sorting.</td>
<td>216</td>
</tr>
<tr>
<td>- the re-sorting of the intermediate fraction.</td>
<td>72</td>
</tr>
<tr>
<td>Air consumption (m³/sec)</td>
<td>0.03</td>
</tr>
</tbody>
</table>

For the sorting machine to function effectively within the processing line, it is necessary to provide two flows: the intermediate fraction flow and the rejected material flow, as shown in Figure 5.
When the sorting machine operates within the processing line, first, raw material gets to the sorter. Then two flows are formed: a pure product flow, which is no longer processed, and an intermediate fraction flow that gets to the intermediate fraction bunker of the sorting machine.

After the intermediate fraction is sorted, two more flows are formed: the rejected material flow that is sorted out and the semi-sorted product flow consisting of the pure rice grains and some non-detected red rice grains. This flow gets back to the raw material bunker and is reprocessed.

**Results:**

Figure 6 demonstrates reflectance (a) and transmittance (b) spectra of the collimated radiation of white and red rice seeds with the high degree of scattering. As the rice seeds are not uniform, the data of no less than 10 spectra was analysed. The spectra show the curves that demonstrate the maximal difference between the grains of the same type. Figure 6(a) demonstrates that it is rather difficult to sort rice grains effectively. Indeed, a little difference becomes obvious only between 600 and 800 nm, which is maximal at 700 nm, but still no more than 10%.

It is, however, possible to solve this problem by using the algorithm for spectral light transmittance through the grains. Thus, Figure 6(b) demonstrates that with the wavelength between 550 and 700 nm it is possible to eliminate shelled red rice grains from the mixture quite effectively.

The results obtained are positive and prove the necessity to develop and apply the suggested sorting algorithm - based on the light transmittance - for separating grains from dockage according to their structural properties.

The efficiency of the fibre optic laser sorter can be proved by the results of separating rice grains of «Yuzhnyi» and «Avstral» varieties from red rice grains by the fibre optic laser sorting machine SV-4.

The amount of the dockage in the «Yuzhnyi» and «Avstral» rice paddy cleaned by air cleaner, a trieur and a gravity table separator was determined using state standard of Russian Federation [8,9].
methods and varied in the range of: pure seeds from 98.06 to 98.34%; amount of: milled seeds from 0.3 to 0.38%, red rice seeds form 1.44 to 2.62%, weed seeds from 0.02 to 0.04%, organic impurities from 1.36 to 1.52%, mineral impurities from 0.26 to 0.44%. The material moisture content was determined in accordance with state standard of Russian Federation [10] and varied from 13.46 to 13.70%, which fits the requirements of state standard of Russian Federation [7] as for the portion of other plants seeds in the rice seeds, but does not fit the requirements of GOST standard as for the portion of red rice seeds. The average grain width of the «Yuzhnyi» rice variety was 2.28 mm with the mean square deviation 0.62 mm, while the average grain width of the «Avstral» variety was 2.06 mm with the mean square deviation 0.63 mm.

After processing the grains by the sorter machine with capacity rate from 0.91 to 1.41 kg/s and the grain loss of 10%, the portion of red rice grains reduced from 2.5 to 2.62% to 0.37 to 0.43%. Thus, when the sorter machine capacity rates are from 0.91 to 1.41 kg/s, the accepted product fits the requirements of state standard of Russian Federation [7] for the reproductive rice seeds, while when the capacity rates from 1.58 to 1.72 kg/s it does not.

Discussion:
It appears that it using standard air cleaning and other methods does not allow to sort out red rice seeds that cause Pircularia oryzae - a highly dangerous disease that can lead to crop failure of up to 25% [12]. It is therefore impossible to fit state standard of Russian Federation [7]. The analysis of reflectance spectra of white and red rice seeds (Fig. 6(a)) demonstrates that standard optical sorters [15,16,6,5], also fail to sort out red rice seeds looking similar to the pure ones.

The analysis of transmittance spectra of the collimated radiation of white and red rice seeds (Fig. 6(b)), however, has shown that another spectral analysis algorithm, i.e. transmittance spectra analysis, can be quite effective. Indeed, only a very small amount of light can be transmitted through long grains of high density and then be registered by the sorting machine camera. This problem, however, can be solved by using laser light sources. The intensity of the laser beam was set so that it would not damage the grains.

The spectral analysis results together with a record of producing traditional color sorting machines, thus enabled the authors to implement a new approach to grain laser sorting, which is based on the analysis of transmitted light spectra. The suggested technologies [4,18], used to construct the fiber optical sorting machine (Figure 4), yielded positive results while used to sort out dangerous red

Table 2: The red rice portion in the «Yuzhnyi» variety processed at different capacity rates of the fibre optic laser sorting machine.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Capacity (kg/s)</th>
<th>0.91</th>
<th>1.11</th>
<th>1.41</th>
<th>1.58</th>
<th>1.72</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red rice grains (%)</td>
<td>0.39</td>
<td>0.44</td>
<td>0.48</td>
<td>0.73</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>Rice seeds loss (%)</td>
<td>6.9</td>
<td>7.5</td>
<td>9.8</td>
<td>13.9</td>
<td>16.8</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: The red rice portion in the «Avstral» variety processed at different capacity rates of the fibre optic laser sorting machine.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Capacity (kg/s)</th>
<th>0.89</th>
<th>1.09</th>
<th>1.40</th>
<th>1.57</th>
<th>1.71</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red rice grains (%)</td>
<td>0.37</td>
<td>0.40</td>
<td>0.43</td>
<td>0.69</td>
<td>1.03</td>
<td></td>
</tr>
<tr>
<td>Rice seeds loss (%)</td>
<td>6.5</td>
<td>7.1</td>
<td>9.4</td>
<td>13.7</td>
<td>17.0</td>
<td></td>
</tr>
</tbody>
</table>
rice grains. Thus, the goal set in the beginning was reached.

Besides, with the sorting machine capacity rate of 0.89 - 1.4 kg/s the final products fits state standard of Russian Federation [7]. With a higher capacity rate, however, the quality of the product became worse, and the good product loss increased (Table 2).

**Conclusion:**

Traditional sorting methods of separating rice seeds from foreign material (such as shelled red rice grains) according to their size, aerodynamic properties, weight, and external features, do not allow to eliminate the dockage completely.

To separate the seeds from the dockage according to their structural properties, a new approach was suggested that applies laser sorting techniques.

When the fibre optic sorters are used to determine whether it is possible to separate the grains from dockage, spectrum analysis methods are usually applied. The method proved that it is not possible to separate shelled pure rice grains from red rice basing on the external features only (by scattering). However, it is possible to eliminate practically all the shelled red rice grains from the mixture by transmitting light stream with the wave length from 600 to 700 nm.

To form high-power light beams that go simultaneously through both the grains and the dockage at various wave length a new fibre optic laser sorting machine and a processing line were constructed, which enables the material flow at the capacity rate from 0.8 to 1.8 kg/s.

Sorting rice seeds of varieties «Yuzhnyi» and «Avstral» by means of the air trieur and the gravity table separator yield the results fitting the requirements of the GOST standard as for the quantity of other plants' seeds in the rice paddy, but the quantity of shelled red rice grains amounted to 1.44...2.62%, which is much higher than the permissible quantity of no more than 0.5% allowed by the GOST standard.

After separating rice seeds of varieties «Yuzhnyi» and «Avstral» from shelled red rice grains by the fibre optic laser sorting machine with higher than nominal capacity rate, the quantity of shelled red rice grains in the accepted material is much higher than allowed by the GOST standards with the pure grain loss of over 10%. The rice seeds do not fit the requirements of state standard of Russian Federation [7] for reproduction seeds.

Fibre optic laser sorting machine eliminates effectively shelled red rice grains at the nominal and less than nominal capacity rate with the grain loss of less than 10%. The cleaned rice seeds fit the requirements of state standard of Russian Federation [7] for reproduction seeds.

The percentage of good product loss, however, can be rather high. In our further work we are going to improve these figures. This can be done by applying fixed orientation of each grain during illumination and various length waves that allow to measure the width of every grain.

**Acknowledgement**

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