Acta Agrophysica, 2013, 20(4), 543-553

PERFORMANCE EVALUATION OF HIGH SPEED COLOUR SORTER FOR CASHEW KERNELS

Balasubramanian Dhakshinamurthy, Joycy Rodrigues Lyra Kokila

Directorate of Cashew Research,
Puttur – 574 202, Dakshina Kannda
Karnataka, INDIA
email: bavika13@email.com

Abstract. Surface colour of cashew kernels is one of the physical attributes used to determine the quality in cashew processing industry. Although manual grading of cashew kernels is followed in the Indian cashew processing system, the mechanised colour grading machine is gaining importance due to shortage of skilled man power. In the study a high speed colour sorter suitable for cashew kernel is evaluated for its performance in terms of operational capacity and purity index. Certain grades of whole kernel and broken kernel grades with different proportions are used. Estimation of the operational capacity revealed significant differences among the grades investigated, with higher value of 156 kg h^{-1} for the largest kernel (WW 210) and 52 kg h^{-1} for the smallest kernels (BB). Purity index showed a dependence on kernel size and was influenced by proportion of the kernels. Cost economics indicated that mechanical grading saves 40% of the total cost incurred for manual grading of cashew kernels.

Keywords: cashew kernel grading, colour sorter, purity index

SYMBOLS

Kg – Kilogram,
h – Hour,
MT – Metric Tonne,
WW210 – White Whole Cashew Kernels 210,
WW320 – White Whole Cashew Kernels 320,
WW450 – White Whole Cashew Kernels 450,
S – Splits,
LWP – Large White Pieces,
BB – Baby Bits,
WI – Whiteness Index,
L – Value or luminance of a colour,

a – Measure from red to green,
b – Measure from yellow to blue,
CCD – Charge Coupled Device,
C – Operational capacity,
Q_t – Total quantity of cashew kernels fed,
T – Time,
PI – Purity Index,
Q_a – Quantity of 'accept' cashew kernel.

INTRODUCTION

India is the global leader in cashew processing and the leading exporter of cashew kernels. About 132 thousand MT of cashew kernels were exported during the fiscal year 2011-12, earning foreign exchange at the level of 43,900 million Rupees (Saroj and Balasubramanian 2013). Colour based classification of cashew kernel determines the market price, with domestic and export trade preferring white wholesome cashew kernels. The colour of an object is determined by wavelength of light reflected from its surface. In biological materials the light varies widely as a function of wavelength. These spectral variations provide a unique key to machine vision and image analysis (Alfatni *et al.* 2008). Machine vision is the most important tool for external feature measurements such as colour intensity, colour homogeneity, bruises, size and shape of cereal and grains (Majumdar and Jayas 2000, lentils (Shahin and Symons 2001) and lemon (Khojastehnazhand 2010). Narendra (2011) developed lab level methodology to grade whole cashew kernels based on their surface texture which works out to the accuracy of 90%. Using electronic colour sorters, shelled peanuts in each grade size are colour sorted wherein discoloured kernels are sorted into the reject category and the better quality peanut kernels are sorted into the accept category (Thomas *et al.* 2005). Rao *et al.* (1999) developed an online apple grading based on some of the most important external parameters including the fruit's surface colour.

Visual inspection of kernel surface colour is one of the processing techniques used as an indicator of end product quality in cashew nut processing. Presently, quality evaluation of cashew kernels in terms of surface colour depends heavily on manual inspection and it is tedious, laborious and costly. Besides, it is easily influenced by physiological factors, inducing subjective assessments leading to inconsistent results. In India, certain physical quality attributes viz., size, wholesomeness and colour are considered while segregating the cashew kernels as per the standards specified by the Export Control and Inspection Act, 1963 (CEPCI 2013). Due to the scarcity of skilled man power, mechanisation at various stages

of processing is gaining importance in this country. Mechanised colour sorter is one such technology introduced in Indian cashew nut processing sector to counteract labour shortage. This research demonstrates the performance of colour sorter applied for grading cashew kernels and its cost economics.

MATERIALS AND METHODS

Cashew kernels obtained by following the steam conditioning method, acquired from a commercial cashew processing unit located in Mangalore, Karnataka, were used for the present investigation. Certain grades of cashew kernels based on wholesomeness, viz., white wholes (WW 210, WW 320 and WW450) and broken kernels (Splits, Large White Pieces and Baby Bits) were sorted out manually following the standard specification prescribed by the Cashew Export Promotion Council (CEPCI, 2012). Colour of both dorsal sides of various cashew kernels was measured using a spectrophotometer (Model: Konica Minolta) in CIELAB scale at 10°observer and D65 illuminant. Based on the L,a,b values observed for the various grades, whiteness index was worked out using the formula:

$$WI = 100 - \sqrt{(100 - L)^2 + a^2 + b^2} \quad (1)$$

where, WI this is different from name of the grade is the Whiteness Index, L is the value or luminance of a colour, a is the measure from red to green, and b is the measure from yellow to blue.

Cashew kernels having whiteness index values ≥20 were considered as 'Accept' fraction and <20 as 'Rejects'. These two fractions were mixed up in different proportions, viz., 1:0 (100% accept cashew kernels), 1:1 (50% accept and 50% rejects), 3:1 (75% accept and 25 5 reject), 1:3 (25% accept and 25% reject) and 0:1 (100% reject kernels) for various grades of cashew kernels, and used while evaluating the performance of the colour sorter.

A high speed commercially available colour sorter (Model: Venus, India) was used for real time evaluation of grading efficiency for selected grades of industrially processed cashew kernels. The colour sorter primarily consists of a feeding mechanism, optical chamber, video camera, electronic section, pneumatic system and product outlets. Cashew kernels from feed hopper are conveyed to vibratory feeder by gravity flow. These kernels are singulated and accelerated downwards while moving along the inclined channels. CCD cameras provided on front and rear side of inclined channels view each kernel once it reaches a specific area. An air ejector is triggered to divert a kernel from its trajectory when cashew kernel

colour, as seen by either one of the cameras, exceeds a set sensitivity (or threshold) level. Diverted kernels fall into a "reject" container, while free-falling kernels fall into an "accept" container (Fig. 1).

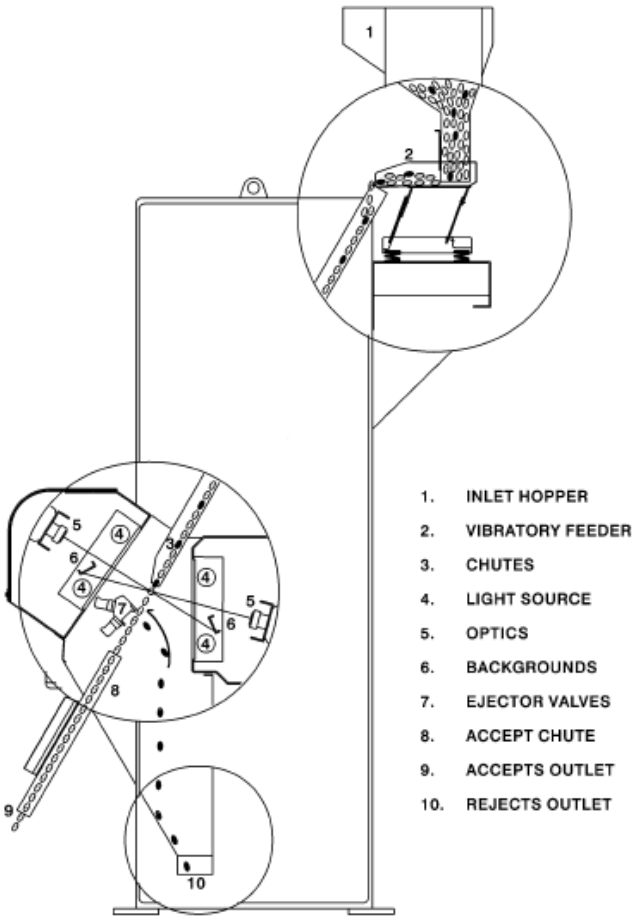

Fig. 1. High speed colour sorter for grading cashew

The tests were conducted with a definite quantity of cashew kernels. i.e. 1 kg, with desired proportion of accepts and rejects of particulate grade (say WW210). Before feeding the material in the feed hopper, the vibratory speed, sensitivity level and air pressure were set based on the preliminary trials (Tab. 1). Time taken for grading a given quantity of pure or mixed proportion of cashew kernels was noted to work out the operational capacity using the following formula:

$$C = \frac{Q_t}{T} \tag{2}$$

where, C is the operational capacity (kg h^{-1}), Q_t is the total quantity of cashew kernels fed (kg), T is the time taken (h).

Random samples of cashew kernels were graded manually into 'Accept' and 'Reject' categories from the total quantity of material received in the 'accept' outlet. Purity index representing the efficiency of grading was worked out using the formula (Omid *et al.* 2010):

$$PI = \frac{Q_a}{Q_t} \tag{3}$$

where, PI is the Purity Index, Q_a is the quantity of 'accept' cashew kernel collected in the accept outlet (kg).

Table 1. Specification of cashew kernel grades and machine parameters of colour sorter

Grade	Specification	Feed vibrator speed	Sensitivity level	Air pressure (MPa)
WW 210	White Whole cashew kernels counting 395 to 465 kernels per kg	38	50	0.7
WW 320	White Whole cashew kernels counting 660 to 706 kernels per kg	38	50	0.7
WW 450	White Whole cashew kernels counting 881 to 990 kernels per kg	38	50	0.7
S	Splits – Kernels split lengthwise naturally	38	32	0.6
LWP	Large White Pieces – Kernel pieces not passing through a sieve aperture 4.75 mm	36	15	0.4
BB	Baby Bits – Kernel pieces passing through a sieve of aperture 4.75 mm, but not passing through a sieve of aperture 2.80 mm	36	12	0.3

The performance evaluation trials were replicated thrice and average value was used for calculation. This procedure was repeated for various grades viz., WW210, WW320, WW450, S, LWP and BB) identified and statistically analysed using SAS software (Tab. 2).

Table 2. Mean values of operational capacity and grading efficiency of colour sorter for cashew kernels

Cashew kernel grades	Operational capacity						Purity index					
	100	75	50	25	0	Mean	100	75	50	25	0	Mean
White whole 210	155.51	153.77	154.20	151.59	152.55	153.52	1.000	0.936	0.924	0.829	0.683	0.874
White whole 210	140.60	137.87	140.27	138.71	137.79	139.05	1.000	0.932	0.898	0.827	0.610	0.853
White whole 210	127.30	125.82	127.30	123.64	123.54	125.52	1.000	0.933	0.883	0.770	0.580	0.833
Splits	78.36	77.27	76.16	75.02	76.46	76.65	1.000	0.880	0.840	0.737	0.507	0.793
Large white Pieces	65.56	66.65	65.56	63.53	63.55	64.97	1.000	0.857	0.803	0.698	0.470	0.766
Baby Bits	51.93	49.55	51.93	48.55	50.95	50.58	1.000	0.798	0.777	0.650	0.410	0.727
Mean	103.21	101.82	102.57	100.17	100.80		1.000	0.889	0.854	0.752	0.543	
Source	Grades (G)		Proportion (P)		G x P		Grades (G)		Proportion (P)		G x P	
SEm±	2.03		1.85		4.53		0.008		0.007		0.018	
LSD	5.77		5.23		12.50		0.023		0.020		0.050	
(P<0.05)	S		NS		NS		S		S		S	

RESULTS AND DISCUSSION

The performance of the colour sorter was evaluated in terms of operational capacity and grading efficiency or purity index based on the data collected using certain identified cashew kernels grades viz., WW 210, WW 320, WW 450, S, LWP and BB. Whiteness index of the above mentioned cashew kernel grades ranged from 38.74 to 23.21. Value of whiteness index ≥20 was considered as 'Accepts' and <20 as 'Rejects' for preparing samples of cashew kernels of identified grades to evaluate the performance of the colour sorter. Most agricultural

applications require analysis on a predefined set or range of colours. Mapping these relevant colours to a small number of indexes allows simple and efficient colour image processing for quality evaluation.

The operational efficiency of the colour sorter for selected grades of industrially processed cashew kernels following steam treatment as conditioning method is depicted in Figure 2. The quantity of cashew kernels graded per unit of time was found to be non-significant for the particular grade of cashew kernels, irrespective of the proportions of accept and rejects in the sample. Operation capacity was found to be more or less uniform for a given size of the cashew kernels, but decreased as the kernel size decreased from WW 210 to BB. Operational capacity recorded for WW210 was found to be in the range of 152 to 156 kg h^{-1} whereas it was recorded between 49 and 52 kg h^{-1} for BB for the various proportions investigated. The number of kernels per unit weight depended on individual weight of the specific grade and it was the reason for the variation in operational capacity for the selected size of cashew kernels. This illustrates that the colour sorter can perform better for larger size kernels wherein product flow is uniform across the viewing area of the optical chamber.

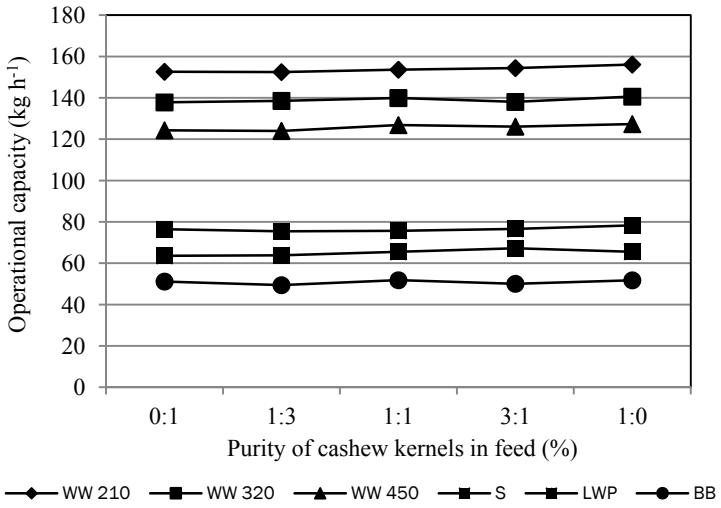

Fig. 2. Changes in the operational capapcity of colour sorter vis-à-vis cashew kernel grades

The grading efficiency of the colour sorter depends on the quantity of rejects collected in the accept outlet and accept in the reject outlet. Purity index worked

out representing the grading efficiency of various grades selected for the colour sorter is shown in Figure 3. Data recorded for various grades of cashew kernels and proportions were found to be significant at $P<0.05$. It was observed that purity index for the largest size cashew kernel, i.e. WW 210, decreased from 1.0 to 0.68, whereas the purity index ranged between 1.0 and 0.41 for the smallest cashew kernels, i.e. BB, for the different proportions of accept and rejects considered. Uniformity in shape which can be detected by the camera is the principal reason for the higher purity index for whole kernels than the broken kernels. As far as the proportions of cashew kernels are concerned, obviously kernel proportion with more quantity of 'accept' showed better purity index than increased proportion of 'rejects' in the sample. Synchronising the kernel passage across the viewing camera and the operation of the pneumatic ejector can be adjusted to improve overall efficiency of the colour sorter irrespective of size of the grades

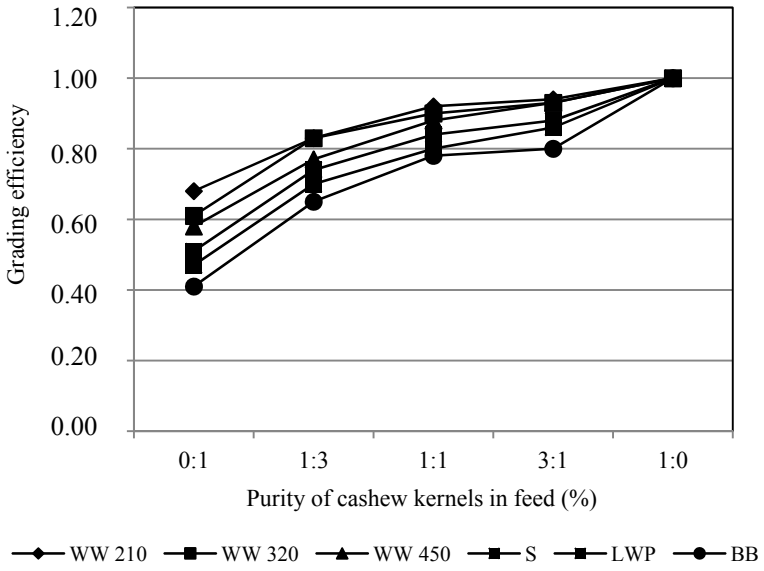

Fig. 3. Changes in the Grading efficiency of colour sorter vis-à-vis cashew kernel grades

Cost economics of the colour sorter worked out for the largest grade (WW 210) and the smallest grade (BB) is presented in Table 3. Based on certain basic assumptions, grading of cashew kernels was computed as Rs 0.73 and 2.20 for WW 210 and BB grades, respectively. It is evident from the cost calculation that

on average 40% of cost incurred towards manual grading could be saved by adopting the mechanised sorter irrespective of kernel grades.

Table 3. Cost economics of colour sorter for cashew kernels

Basic assumptions		
Capacity of colour sorter	**For WW 210 grade**	**For BB grade**
Mechanised	156.0 kg h^{-1}	52.0 kg h^{-1}
Manual	15.0 kg h^{-1}	4.4 kg h^{-1}
Life span of colour sorter (N)	20 Years	
Initial cost of colour sorter (C)	Rs 75000	
Annual usage		
For WW 210 grade	312 TPA	
For BB grade	104 TPA	
Interest (i)	10%	
Energy required (8h a day)	3.73 kWh	
Electricity charges (Rs /kWh)	Rs 5.50	
Fixed cost (FC)		
Annualised fixed cost of the unit (Rs)	$\frac{i*(i+1)^N}{(i+1)^{N-1}} xC$	88095.00
Housing, Insurance and taxes (Rs)	2.5 %	15000.00
Total fixed cost (Rs)		103095.00
Variable cost (VC)		
Electricity charges (Rs)		41030.00
Repair and maintenance (Rs)	3.0 %	22500.00
Total variable cost (Rs)		126030.00
Total cost (FC+VC) (Rs)		229125.00
	WW 210 grade	**BB Grade**
Cost per kg (Machine)	0.73	2.20
Cost per kg (Manual)	1.20	4.29

CONCLUSIONS

1. A high speed colour sorter suitable for grading cashew kernels was evaluated for its performance in terms of operational capacity and grading efficiency.

2. Operational capacity showed significant difference for the selected grades of cashew kernels which are either whole or broken in their form. Largest kernel (WW 210) performed better than smallest cashew kernels (BB) and individual kernel weight was a contributing factor.

3. Grading efficiency or purity index decreased with decrease in size of the kernel irrespective of the proportion of accept and reject in the kernel mixture.

4. Shape factor could be one of the reasons for variation in the purity index with reference to colour grading of kernels investigated.

5. Purity index was influenced by the proportion of rejects irrespective of the grades of cashew kernels.

6. Mechanised colour sorter could help the Indian cashew processors to overcome the problem of skilled manpower, saving the cost incurred in grading to the extent of 40%.

ACKNOWLEDGEMENT

This research work was carried out as a part of National Agricultural Innovation Project taken up at Directorate of Cashew Research, Puttur, Karnataka, India. Author is thankful to Indian Council of Agricultural Research, India and also to Director of Cashew Research, Karnataka state, India for providing facilities to take up the investigation.

REFERENCES

Alfatni M.S.M., Shariff A.R.M., Shafri H.Z.M., Saeed O.M.B., Eshanta O.M., 2008. Oilpalm fruit grading system using red, green and blue digital number. J. Applied Sciences, 8(8), 1444-1452.

CEPCI, 2013. http://www.cepci.org.

Khojastehnazhand M., Omid M., Tabatabaeefar A., 2010. Development of a lemon sorting system based on color and size. African Journal of Plant Science, 4(4),122-127.

Majumdar S., Jayas D.S., 2000. Classification of cereal grains using machine vision: II- Color models. Transaction of ASAE, 43(6), 1677-1680.

Narendra V.G., Hareesh K.S., 2011. Cashew kernels classification using texture features. International Journal of Machine Intelligence, 3(2),45-51.

Omid M., Sharouzi M., Keyhani A.R., 2010. Development of an Automated Machine for Grading Raisins based on Color and Size. Journal of Modelling and Simulation of System, 1(3),157-162.

Rao S.P., Gopal A., Revathy R., Meenakshi K., 1999. Colour analysis of fruits using machine vision system for automatic sorting and grading. J. Instrum. Soc. India, 34,284-291.

Saroj P.L., Balasubramanian D., 2013. Cashew Industry in India – a sustainable road map. Indian Horticulture, 58(1),9-15.

Shahin M.A., Symons S.J., 2001. A machine vision system for grading lentils. Canadian Biosystems Engineering, 7, 7-14.

Thomas B.W., Dorner J W., Lamb, M., Slate A B., 2005. The Effect of Sorting Farmers' Stock Peanuts by Size and Color on Partitioning Aflatoxin into Various Shelled Peanut Grade Sizes. Peanut Science, 32,103-118.

OCENA SPRAWNOŚCI SEPARATORA BARWNEGO DO ORZECHÓW NERKOWCA

Balasubramanian Dhakshinamurthy, Joycy Rodrigues Lyra Kokila

Puttur – 574 202, Dakshina Kannda
Karnataka, INDIA
email: bavika13@email.com

S t r e s z c z e n i e . Barwa powierzchni orzechów nerkowca jest jedną z cech fizycznych, określających ich jakość w przemyśle przetwórczym. W Indiach dominuje sortowanie ręczne w przetwórstwie orzechów nerkowca, ale zmechanizowane systemy separacji zyskują na znaczeniu z uwagi na brak wykwalifikowanej siły roboczej. W pracy oceniono wydajność operacyjną i indeks czystości separatora barwnego do orzechów nerkowca. W badaniach uwzględniono wybrane kategorie orzechów całych oraz rozdrobnionych, w różnych proporcjach. Wydajność operacyjna charakteryzowała się znaczącym zróżnicowaniem różnych wielkości orzechów nerkowca, przy czym wyższą wartość 156 $kg \cdot h^{-1}$ otrzymano dla największych orzechów (WW 210), a wartość 52 $kg \cdot h^{-1}$ dla orzechów najmniejszych (BB). Indeks czystości zależał od wielkości oraz udziału orzechów małych i dużych. Zastosowanie separatora barwnego pozwala zmniejszyć koszty separacji o 40% w porównaniu do kosztów sortowania ręcznego.

S ł o w a k l u c z o w e : separacja orzechów nerkowca, separator barwny, indeks czystości