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Determination of key parameters for grading dehusked coconut using principal component analysis

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Abstract

Grading of the coconuts adds value to the product and gives better economic return to the farmers as grading reduces the ambiguity in pricing. The aim of the study was to identify the suitable parameters for grading dehusked coconut. In this study, major diameter, minor diameter, length, weight of nut, shell, copra, kernel and water, thickness of shell and kernel were considered. The Principal Component Analysis (PCA) was performed to achieve the least possible number of parameters which govern an original variation in the dehusked coconut. From the PCA results, two plots *viz.*, score plot and loading plot were obtained for three different size ranges of dehusked coconut (80-90, 91-100 and 101-110 mm diameter). The loading plot revealed that, the weight of nut and weight of kernel were the important variables in all the ranges of sizes of dehusked coconut. Score plot was helpful to find the variation between the weights of nut in each size range of dehusked coconuts. Therefore, the present study concluded that the dehusked coconut can be graded by size as well as weight which may fetch more profit to the coconut producers rather than grading manually by size alone.

Key words: Coconut, principal component analysis, score plot, grading

Introduction

Coconut is one of the most valuable crops of the wet tropics and is considered to be among the 20 most important crop plants in the world (Vietmeyer, 1986). It is widely called as *kalpavriksha* which means Tree of Heaven. Products derived from coconut are exported worldwide namely, copra in desiccated and solid form, coconut cream, full nut, coir, activated carbon etc. Along with the above products, charcoal from shell, mature nuts for cooking and food uses, brooms, ropes, and coconut shell products are attracted in overseas markets (Foale, 2003). The crop is also valuable because of its flexibility within farming systems; intensive farming results in high productivity (Moore and Howard, 1996).

Worldwide, almost 71000 million nuts are produced from 12.44 million hectare area (Coconut Development Board, 2016). India, Sri Lanka, Indonesia, Philippines, Brazil, Thailand, Mexico, Vietnam and Papua New Guinea are the top coconut producing countries. Among these countries, India is at the top of the list and the cultivation is spread across the coastal track of different states across Tamilnadu, Kerala, Andhra Pradesh, Karnataka, Pondicherry, Orissa, West Bengal and Maharashtra and islands such as Andaman and Nicobar. The average coconut productivity in the country is 10614 nuts per hectare which shares more than Rs. 10000 crores per year to GDP.

From the marketing point of view, the fruits must be of certain standards in order to be efficiently offered to better quality market, thus fruit sorting is essential in postharvest handling. In India, coconuts are mostly segregated manually based on size and tapping the shell with the finger (gives a metallic sound). However, the coconut with same variety and maturity differs in its size, weight, kernel thickness, kernel size and different cavity. Marketing of coconut have series of activities from the farmer to the end use consumer. Unfortunately, intermediate channels that play a major role in marketing are benefited more than farmers who produce it. In India, farmers sell the coconut just by manual inspection without any grading techniques. Therefore, it is essential to find the governing factors, which leads to the variation in dehusked coconut to have accurate grading technique.

PCA is used to reduce dimensionality and to achieve the least possible number of components which govern original variation of multivariate data. Among the dependent variables PCA identifies the pattern of correlations, then it substitute a new variable called as 'factor' for group of correlated original characteristics. Based on the residual variance, the second and third group are identified with derivation of factors. Li *et al.* (2018) used principal component analysis to find the effect of antioxidant activity of blackberry treated with 1-methycycopropene and vacuum cooling. From the scores of PCA they concluded that H_2O_2 was the most important variable in blackberry fruit. To identify the most attractive cultivars from the selected twenty cultivars PCA model was used by Nowicka *et al.* (2019). From the above studies it was understood that PCA is the best tool to identify the key parameter which is responsible for variation.

The principal component can be used as grading parameter of dehusked coconut. The objective of the present study was to identify the principal component in the dehusked coconut with different range of sizes.

Materials and method

Sample collection: In the present investigation, coconut variety West Coast Tall was used as it is commonly grown variety in

South India. Coconuts were harvested from trees bearing 12-13 months old fruits. The fruit contain the nut enclosed by the husk of fibrous layers. To determine the fruit characteristics the outer husk was removed. The dehusked coconut was then categorized into three different size ranges namely 80-90, 91-100 and 101-110 mm diameter. From each size range, 75 nuts were taken to show the significant variation between the selected size range of dehusked coconut.

The variables chosen for PCA analysis were weight of nut, major diameter, minor diameter, length, weight of shell, weight of fresh kernel, weight of copra, weight of water, thickness of shell, thickness of kernel of dehusked coconut and sphericity.

Fruit characteristics: For each fruit, principal dimensions, such as length, major diameter (width) and minor diameter (thickness) were measured using a Digital Vernier Caliper. The least count and accuracy of the Vernier Caliper used for measurement was 0.01 mm and ± 0.05 mm, respectively. The width and thickness of the coconut measured were perpendicular to each other. To obtain the mass, each fruit was weighed (w₁) with an electronic balance of ± 0.01 g accuracy.

Fruits were carefully opened to avoid any damage of the kernel and shell. The coconut water was drained off and again the weight was measured (w_2). Thickness of both the kernel along with shell was measured using screw gauge (least count 0.01mm) (t_1). By subtracting w_1 and w_2 the amount of coconut water (w_3) present in each fruit was calculated. The wet flesh of coconut was sun dried to determine the weight of copra (w_4). Coconuts were sun dried to attain a moisture content of 8% (w.b.) and then shell was removed. The weight of shell of each fruit was measured (w_5). Weight of kernel (w_6) was calculated by subtracting w_2 and w_5 . Thickness of the shell (t_2) was also determined using screw gauge. By subtracting the t_1 and t_2 thickness of the kernel was determined.

Statistical analysis: All the data obtained were analysed and interpreted by principal component analysis with Minitab 17 statistical software.

Results and discussion

From the PCA results, two plots *viz.*, score plot and loading plot were obtained. Principal components (PC) with high eigenvalues represent maximum variation among the variables. Most of the studies have assumed PCs with eigenvalue greater than one (Puri *et al.*, 2016; Atanu and Rattan, 2014) represents the maximum variation.

Table 1 shows the PCs with eigenvalues greater than one explained the total variations of 87.3 %. The results revealed that, PC1 with eigenvalue of 4.41 was able to explain 40 % of the total variation and PC2 was also able to explain 25 % of variation and both the PCs (PC1 and PC2) explained 65 % of the total variation. Similarly, PC3 and PC4 were able to explain 12 and 9 %, respectively. The factor loadings of respective variables are presented in Table 1 and it shows that the highest factor loading value gives the chief important variable under a certain PC and absolute factor loading value within 10 % of the highest values under same PC. Thus, PC1 explains more about the weight of nut, length, weight of copra and weight of kernel. Further, PC2 was influenced by major and minor diameter of the nut and PC3

Table 1. PCA for dehusked coconut size ranging from 80-90 mm

	PC1	PC2	PC3	PC4
Eigenvalue	4.411	2.749	1.4019	1.0439
Proportion	0.401	0.250	0.127	0.095
Cumulative variability (%)	40.1	65.1	77.8	87.3
Factor Loading				
Weight of nut	0.430	0.172	-0.102	-0.249
Major diameter	0.074	0.500	-0.296	0.221
Minor diameter	0.087	0.519	-0.247	0.151
Length	0.408	-0.236	0.050	-0.039
Weight of shell	0.302	-0.171	-0.469	0.198
Thickness of shell	0.091	-0.326	-0.587	0.050
Weight of copra	0.410	0.026	0.157	0.069
Weight of kernel	0.421	0.170	0.107	0.119
Weight of water	0.151	0.276	0.022	-0.775
Thickness of kernel	0.223	0.120	0.468	0.442
Spericity	-0.345	0.375	-0.133	0.090

explains about weight and thickness of the shell. Moreover, PC4 had the highest factor loadings for weight of water and thickness of the kernel.

The PCA loading plot drawn between PC1 and PC2 is presented in Fig.1. It was observed that the spoke length of the weight of nut, weight of kernel and spericity was longest among all the characteristic of dehusked coconut of size 80-90 mm and therefore it was proved as a most interactive character of dehusked coconut. However, weight of fresh kernel and weight of nut had similar character as it had a small angle within them. Similarly, major diameter and minor diameter had similar character. However, minor diameter, weight of water, thickness of kernel, weight of copra, length and thickness of shell have different characters for the dehusked coconut size ranging from 80-90 mm, due to high angle between them.

In Fig. 2, the data obtained from the nut size 80-90 mm was grouped based on the weight of the nut as 300-400 and 401-500 g. The score plot obtained has revealed the variation between the two groups. The clear separation between the coconut samples pointed out the differences in weight of coconut of size 80-90mm.



Fig. 1. PCA loading plot for dehusked coconut with size ranging from 80-90 mm



Fig. 2. PCA score plot for dehusked coconut with size ranging from 80-90 mm

The PCA for dehusked coconut size ranging from 90-100 mm is presented in the Table 2. From the table it was inferred the four PCs with eigenvalues greater than one had the cumulative variability of 85.5 %. As discussed in the previous section, PC1 explains more about the weight of the nut (0.455) followed by the weight of fresh kernel (0.391) whereas, PC2 has highest factor loading for spericity. This depicts that all three dimensions such as major, minor diameter and length of the coconut have equal importance in PC2 whereas PC3 was influenced by weight and thickness of the shell. It is noticed that the PC4 was influenced by the thickness of the kernel. The loading plot of the dehusked coconut with size ranging from 90-100 mm is shown in Fig 3. Similar to the results of coconut with size 80-90 mm, weight of the nut and the weight of kernel have longest spoke length. The spoke length of thickness of shell and thickness of kernel are approximately same which indicate that these variables had similar characters. In Fig. 4, three groups of weight of coconut viz., < 400, 401-500 and > 501 g can be clearly distinguished and this shows the variations in weight of coconut with size ranging from 90 to 100 mm. The PCA for dehusked coconut size ranging from 100-110 mm is shown in Table 3 and it was observed that 86.5 % of cumulative variability

Table 2. PCA for dehusked coconut size ranging from 90-100 mm

PC1	PC2	PC3	PC4
4.4819	2.5607	1.346	1.0132
0.407	0.233	0.122	0.092
40.7	64.0	76.3	85.5
0.455	0.022	0.050	-0.096
0.353	0.342	-0.086	-0.019
0.357	0.347	-0.096	-0.006
0.249	-0.481	0.054	-0.259
0.307	-0.132	-0.425	0.295
0.076	-0.179	-0.744	0.129
0.325	-0.170	0.096	0.187
0.391	-0.160	0.186	-0.063
0.325	0.246	0.196	-0.298
0.111	-0.118	0.391	0.799
-0.050	0.594	-0.097	0.231
	PC1 4.4819 0.407 40.7 0.455 0.353 0.357 0.249 0.307 0.076 0.325 0.391 0.325 0.111 -0.050	PC1 PC2 4.4819 2.5607 0.407 0.233 40.7 64.0 0.455 0.022 0.353 0.342 0.357 0.347 0.249 -0.481 0.307 -0.132 0.076 -0.179 0.325 -0.170 0.391 -0.160 0.325 0.246 0.111 -0.118 -0.050 0.594	PC1 PC2 PC3 4.4819 2.5607 1.346 0.407 0.233 0.122 40.7 64.0 76.3 0.455 0.022 0.050 0.353 0.342 -0.086 0.357 0.347 -0.096 0.249 -0.481 0.054 0.307 -0.132 -0.425 0.076 -0.179 -0.744 0.325 -0.170 0.096 0.391 -0.160 0.186 0.325 0.246 0.196 0.111 -0.118 0.391

is from the first four PCs. As similar to the results of Table 1 and Table 2, the factor loading obtained from PC1 explained more about weight of nut and weight of kernel. In Fig. 5, huge angle between the weight of nut and weight of kernel shows the different interactive character between them. The score plot presented in Table 3. PCA for dehusked coconut size ranging from 100-110 mm

	PC1	PC2	PC3	PC4
Eigenvalue	3.8365	2.5984	1.8648	1.2205
Proportion	0.349	0.236	0.17	0.111
Cumulative variability (%)	34.9	58.5	75.5	86.5
Factor Loading				
Weight of nut	0.445	0.196	-0.141	0.103
Major diameter	0.271	0.403	0.283	0.019
Minor diameter	0.260	0.427	0.273	-0.115
Length	0.375	-0.177	-0.374	0.105
Weight of shell	0.193	0.265	-0.337	-0.513
Thickness of shell	-0.162	0.247	-0.380	-0.518
Weight of copra	0.349	-0.238	0.213	-0.252
Weight of kernel	0.444	-0.18	0.137	-0.104
Weight of water	0.203	0.333	-0.167	0.540
Thickness of kernel	0.205	-0.363	0.335	-0.233
Spericity	-0.234	0.352	0.473	-0.114







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90-100 mm

Size (mm)	Weight (g)	Grade designation
80-90	300-400	Grade - VIII
	401-500	Grade - VII
90-100	<400	Grade - VI
	400-500	Grade - V
	>500	Grade - IV
100-110	<600	Grade - III
	600-700	Grade - II
	>700	Grade - I

 Table 4. Suggested grading standards for dehusked coconut



Fig. 5. PCA loading plot for dehusked coconut with size ranging from 100-110 mm



Fig. 6. PCA score plot for dehusked coconut with size ranging from 100-110 mm

Fig. 6. visually infers that the differences in the weight of coconuts of size 100-110 mm.

Based on the PCA results the weight of nut and weight of fresh kernel are the principal component in the eleven measured variables. However, from the score plot it was interpreted that the selected three size ranges of dehusked coconut shows a significant difference in weight. The PCA suggest that the PCs weight of nut, weight of kernel, size of coconut, weight and thickness of the shell had explained much of the variation in size and weight attributes of the coconut. From the above results the grading standards for dehusked coconut were formulated and are presented in Table 4. It is suggested that the dehusked coconut can be graded in three different size ranging from 80 to 110 and also this can be again segregated by weight which in turn gives eight grading designation of dehusked coconut.

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