Journal of AgriSearch, 10 (1): 49-52
An Open Access International Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v10i01.12257

Physical Properties of Black Pepper for designing a Robotic Black Pepper Harvester

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ABSTRACT

Agricultural robots were designed based on the characteristics of the target crop. In this study, two varieties of black pepper including *Kaimunda* and *Panniyur 1* were evaluated for physical parameters to design a robotic black pepper harvester. The main objective of this study was to measure and analyze the physical properties of black pepper to design the robotic pepper harvester. In this regard, studies were conducted for pepper spike, pepper peduncle, pepper berry, and pepper vine separately. The results showed that the average length and diameter of pepper spikes of *Karimunda* and *Panniyur 1* respectively as 10.4 cm and 1.10 cm; and 12.8 cm and 1.30 cm. In an average the tested peppers have a berry diameter of 0.42 cm and RGB value of (20, 39, 3) - (255, 224, 111) for *Karimunda* variety and 0.59 cm and (35, 54, 10) - (255, 240, 100) for *Panniyur 1* variety. Based on the shear strength analysis, at a cutting speed of 0.1 mm s^{-1}, the average shear strength of the peduncle was obtained as 1718.6 N mm^{-2} for *Karimunda* and 1671 N mm^{-2} for *Panniyur 1*. And at cutting speed 1 mm s^{-1}, the average shear strength peduncle of *Karimunda* and *Panniyur 1* respectively is 1535 N mm^{-2} and 1544 N mm^{-2}. The average length of the peduncle of *Karimunda* and *Panniyur 1* respectively as 1.2 cm and 1.3 cm, and the diameter of both varieties was 0.17 cm. The maximum leaf coverage of the pepper vine ranges from 10 to 91, and the 95th percentile of the data was 76 cm.

Keywords: Black pepper, Robotic harvester, Black pepper harvesting, physical properties

ARTICLE INFO

Received on	:	17.05.2022
Accepted	:	04.01.2023
Published online	:	30.03.2023

INTRODUCTION

Black pepper known as the "king of spice" is one of the most widely consumed spices in the world (Wang *et al.* 2021). India is the third largest producer of black pepper producing 53,000 tons and largely exported from India. Black pepper is perennial vine growing on supporting stakes. It can grow up to a height of 10 m, but plant is restricted to a height of 3m. The fruit also called as peppercorns or pepper spikes are having drupes of 5 mm diameter. Generally, pepper plucking is done manually by climbing on the tree using bamboo poles, ladders or rope rings. This process of plucking the pepper involves high risk due to falling from the ladder or the bamboo pole. The conventional method results high risk of back strain and musculoskeletal problems to labours due to repetitive hand motions and ascending and descending on ladders with heavy loads. In future, the labour issue is expected to become more critical in terms of both increasing cost and uncertain availability of skilled labours. Another conventional method for harvesting is using poles attached with knife for plucking.

Identifying correct stage of maturity is essential to produce high quality pepper spikes. Existing harvesting methods cannot offer harvesting at correct maturity stage. Black pepper is rich in anti-oxidants and anti-inflammatory compounds which helps to balance the blood sugar and cholesterol level. Also, it has cancer resisting properties and improves degenerative and damaged brain cells (Meixner 2019). To ensure the quality of pepper, it should be harvested at its proper maturity stage. The accuracy or precision of harvesting depends on the experience of the person doing the work.

Robotic harvesting is a promising option to harvest black pepper at correct maturity stage and to meet the increasing labour demand. Identification of matured fruits, plucking, depositing it to a specified location and controlling the entire unit are the major functions of a robotic harvester. The agricultural robots were made a new perspective for future farming (Roshanianfard and Noguchi 2018). In this regard, many of the researchers are focused on agricultural robots. Machine vision system, manipulator, end effector and control unit are the major components of a robotic harvester. Bhartiya and Ashish (2015) developed a machine vision system to identify red rose flowers automatically. Song *et al.* (2019) developed a machine vision system for a kiwifruit harvesting robot that can work a full day. Bulanon *et al.* (2015) developed a machine vision system to recognize apples from other tree parts like a branch and the leaf and to locate the center of the fruit and its abscission layer. Zhao *et al.* (2016) developed robotic tomato harvester with dual arms. Lili *et al.* (2017) developed a tomato harvesting robot with five degrees of freedom manipulator. Rana and Roy (2017) developed an autonomous robotic arm with 4 DOF similar to a human arm. Williams *et al.* (2019) developed a robotic kiwifruit harvester with multiple arms. Yang *et al.* (2020) developed a robot pumpkin harvester to solve the lack of the labour force for harvesting pumpkins.

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Hence, before developing a robotic harvester, it was needed to characterize the physical properties of the crop. This study has presented the physical properties of black pepper spikes that directly or indirectly affect the design and development of robotic harvester for black pepper.

MATERIALS AND METHODS

The study was conducted at Kelappaji College of Agricultural Engineering and Technology, Tavanur, Kerala. Two different varieties of black pepper, *Karimunda* and *Panniyur 1* were considered for the study. The samples were collected from different part of Kerala such as Kattappana in Idukki district, Tavanur in Malappuram district, and Thannithode in Pathanamthitta district. The study was conducted separately for pepper spike, pepper peduncle, pepper berry and pepper vine. The measurements were taken from 100 samples. The measured physical properties include length of the spikes, diameter of the spikes, colour of berries, diameter of berries, length of the peduncle, diameter of the peduncle, shear strength of pepper peduncle and leaf coverage of black pepper vine.

Pepper spike

The length and diameter of the pepper spikes were studied for designing the harvester. Length of black pepper spikes were taken for the estimation of the size of a black pepper spike. It was measured as the total length from the top end of black pepper spike to its bottom tip excluding the peduncle length. It was measured using a steel rule. Diameter of the pepper spikes at three levels viz. top end, middle and bottom was measured for size estimation. The average of three values were recorded as average diameter of spikes. The diameter of spikes was measured using a vernier caliper. The length and diameter of pepper spikes are crucial parameters for designing the gripper, conveyor and storage unit of the robotic harvester.

Pepper berry

The properties such as colour and diameter of the pepper berries were studied. Based on these properties, the matured pepper spikes were identified by the machine vision system. The colour value was measured using the RGB colour model and it was measured using a computer program written in python language. The diameter of the berries was measured using a vernier caliper. The black pepper become matured when one or two berries turns to red from green. Also, diameter of matured berry is higher than that of under matured berry. So colour and diameter of the berries are the parameters were analyzed to identify matured black pepper spikes.

Pepper peduncle

Peduncle is the stem attaching the fruit to the plant. The length, diameter and shear strength of the pepper peduncle were studied for designing the end effector of the harvester. End effector is the attachment at the end of the robotic arm to detach the fruit from the plant. Hence to design the end effector for pepper spikes, study should be made on the length, diameter and shear strength of the pepper peduncle. Its length measured from the top end of the pepper spike to the node on the stem. It was measured using a steel rule and the diameter of the peduncle was measured using vernier caliper. The shear strength of the peduncle was calculated from the shear force and cross-sectional area of the peduncle. Shear force was determined using EZ-SX Texture Analyzer with the operation software TRAPEZIUM X. The cutting probe (blade) with 2.95 mm thick and 30-degree angle was used for this test. The shear strength of the peduncle at two different speed such as 0.1mm s^{-1} and 1mm s^{-1} were determined. Shear strength can be calculated using the equation (Heidariand and Chegini 2011).

$$\text{Shear strength (N mm}^{-2}) = \frac{\text{Shear force, N}}{\text{Cross-sectional area, mm2}}$$

Pepper vine

Leaf coverage of black pepper over the supporting element was studied. It was measured to decide the minimum and maximum reach of the robotic arm. A sample of 50 black pepper vines were observed for conducting this study. Leaf coverage was measured as the horizontal distance from the supporting tree to the extreme end of the black pepper covering. The dimension from four sides were measured and the 95th percentile of the observed values have to be considered for the design purpose.

Fig 1. Measuing physical properties of black pepper

RESULTS AND DISCUSSION

Pepper spike

The length of the pepper spike measured from 100 pepper spikes in each variety showed that *Karimunda* variety has an average length of 10.4 cm and *Panniyur 1* variety has 12.8 cm. The diameter of the spike was 1.10 cm in *Karimunda* and 1.3 cm

in *Panniyur 1*. The average length and diameter of each variety has no significant difference so the average length of the pepper spike can be considered as 12 cm and average spike diameter as 1.2 cm. so the conveyor and storage unit of the harvester should be capable of handling spike with length 12 cm and diameter 1.2 cm.

Pepper berry

The diameter and colour of the pepper berry were important for identifying matured black pepper spikes. The RGB value in *Karimunda* variety obtained as (20, 39, 3) - (255, 224, 111) and *Panniyur 1*as (35, 54, 10) - (255, 240, 100). The average berry diameter was 0.42 cm in *Karimunda* and 0.59 cm in *Panniyur 1* variety. So, the average diameter of pepper berry taken as 0.5 cm. The pepper spikes with berries of diameter greater than0.5 cm and RGB value (20, 39, 3) - (255, 240, 100) can be considered as matured spikes. These are important features of the pepper for identifying matured black pepper spikes through machine learning techniques.

Pepper peduncle

Pepper harvesting has done by cutting the peduncle of the pepper. So it is important to measure the diameter, length and shear strength of the pepper peduncle. The average length of the peduncle obtained as 1.2 cm and 1.3 cm respectively in *Karimunda* and *Panniyur 1* variety. Also, the average diameter of the peduncle obtained as 0.17 cm for both the variety. The shear strength of the peduncle at 0.1 mm s^{-1} cutting speed was 1718.6 N mm^{-2} for *Karimunda* and 1671 N mm^{-2} for *Panniyur 1*. And at a cutting speed of 1 mm s^{-1}, the shear strength was 1535 N mm^{-2} in *Karimunda* and 1544 N mm^{-2} in *Panniyur 1*. So, the cutting unit of the harvester should be strong enough to handle a pepper peduncle with length 1.3 cm, diameter 0.17 cm.

Pepper vine

The maximum leaf coverage of black pepper vine ranges from 10 cm to 91 cm. The 95thpercentile of the data was 76cm. Leaf coverage determined to decide the minimum and maximum reach of the robotic arm. Hence, the manipulator of the robotic black pepper harvester should have a minimum reach of 76 cm.

CONCLUSION

Each component of the robotic harvester should be designed based on the properties of the fruit to be harvested. In this paper, the properties of black pepper were studied to design a robotic black pepper harvester. Study was conducted for two varieties of black pepper; *Karimunda* and *Panniyur 1* to decide the dimensions of black pepper harvester. The length of the pepper spike ranges from 4.5 to 18 cm, diameter of the spike ranges from 0.77 to 1.7 cm, colour of the berries from (20, 39, 3)-(255, 240, 100), diameter of the berry from 0.3 to 0.7 cm, length of the peduncle from 0.4 to 3.0 cm, diameter of peduncle from 0.1 to 0.2 cm, and the leaf coverage from 10 to 91 cm. The shear strength ranges from 1671 to 1718.58 N mm^{-2} at cutting speed of 0.1 mm s^{-1} and from 1535.06 to 1544.5 N mm^{-2} at a cutting speed of 1 mm s^{-1}.

The results of all experiments presented are required parameters to design and develop a robotic black pepper harvester. This study could make a good infrastructure by understanding the physical properties of black pepper.

ACKNOWLEDGEMENT

We acknowledge All India Co-ordinated Research Project (AICRP) and Kerala Agricultural University for financially supporting us to complete this study.

Table 1: Physical properties of black pepper

Sl. No.	Property		*Karimunda*		*Panniyur 1*	
			Range	Average	Range	Average
1	Length of spikes, cm		4.50-13.80	10.4	7.00-18.00	12.8
2	Diameter of spike, cm		0.77-1.30	1.10	0.86-1.70	1.30
3	Colour of berries		(20, 39, 3)- (255, 224, 111)		(35, 54, 10) - (255, 240, 100)	
4	Diameter of berries, cm		0.30 – 0.50	0.42	0.45 – 0.70	0.59
5	Length of the peduncle, cm		0.40-2.10	1.20	0.80-3.00	1.30
6	Diameter of the peduncle, cm		0.10-0.20	0.17	0.10-0.15	0.17
7	Shear strength pepper peduncle, N mm^{-2}	Cutting speed, 0.1 mm s^{-1}	1718.58		1671.00	
		Cutting speed, 1 mm s^{-1}	1535.06		1544.50	
8	Leaf coverage of black pepper vine, cm		Leaf coverage		10 .00- 91.00	
			95th percentile of data		76.00	

REFERENCES

Bhartiya C and Ashish P.2015. Image processing based rose harvesting system using raspberry pi. *In. Journal of Engineering and Tech.* **4**(4):1049-1052.

Bulanon DM, Kataoka T, Ota Y and Hiroma T.2015.A Machine vision system for the apple harvesting robot. *Agricultural Engineering International: the CIGR J. of Scientific Research and Development* **3**:1-11.

Heidari A and Chegini G.2011. Determining the shear strength and picking force of rose flower. *Electronic Journal of Polish Agricultural Universitie.* **14**(2): 1-11.

Lili W, Bo Z, Jinwei F, Xiaoan H, Shu W, Yashuo L, Qiangbing, Z and Chongfeng W.2017. Development of a tomato harvesting robot used in greenhouse. *International Journal of Agricultural and Biological Engineering* **10**:140-149.

Meixner M. 2019. 11 Science-Backed Health Benefits of Black Pepper. Available: https://www.healthline.com/nutrition/black-pepper-benefits

Rana MT and Roy A. 2017. Design and construction of a robotic arm for industrial automation. *International Journal of Engineering and Technology* **6**(5):919-922.

Roshanianfard A and Noguchi N. 2018. Characterization of pumpkin for a harvesting robot. *IFAC-PapersOnlne* **51**(17): 23-30.

Song Z, Fu L, Wu J, Liu Z, Li R and Cui Y.2019. Kiwifruit detection in field images using faster R-CNN with VGG16. *IFAC-PapersOnLine*. 52(30):76-81.

Wang Y, Chen L, Chaisiwamongkhol K, Couto RAS and Compton RG. 2021. Electrochemical quantification of piperine in black pepper. *Food Chemistry* **339**:127892

Williams HAM, Jones MH, Nejati M, Seabright MJ, Bell J, Penhall ND, Barnett JJ, Duke MD, Scarfe AJ, Ahn HS, Lim J and MacDonald BA.2019. Robotic kiwifruit harvesting using machine vision, convolutional neural networks, and robotic arms. *Biosystem Engineering* **181**:140-156.

Yang L, Tian R, Wang Q, Hoshino Y, Yang S and Cao Y.2020. Optimal design and simulation of a robot hand for a robot pumpkin harvesting system. *Int. Robotics & Automation Journal* **6**(1):1-5.

Zhao Y, Gong L, Liu C and Huang Y.2016. Dual-arm robot design and testing for harvesting tomato in greenhouse. *IFAC-Papers OnLine* **49**(16):161-165.

Citation:

Ajayan AV and Bhaskar S.2023. Physical properties of black pepper for designing a robotic black pepper harvester. *Journal of AgriSearch* **10**(1): 49-52