Proceedings of the 2016 International Conference on Food Properties (ICFP2016)
Bangkok, Thailand, May 31-June 2, 2016

Effect of moisture content on physical properties of sal *(Shorea robusta)* seeds

Shashikumar. C*, Dr. Rama Chandra Pradhan*#, Dr. Sabyasachi Mishra*
*Department of Food Process Engineering,
National Institute of Technology (NIT), Rourkela, Odisha

#Corresponding author: Dr. Rama Chandra Pradhan

Abstract

Shorea robust commonly known as sal, play an important role in food, non-food industries. It is mainly processed for extraction of its oil. It can be used for cocoa based products and also used in bio-diesel production. This study was conducted to investigate the effect of moisture content (6.38 to 21.95% (d.b.)) on physical properties of sal seeds. Physical properties such as length, width, arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio, surface area, unit seed mass, bulk density, true density, porosity, and coefficient of friction with various surfaces namely, galvanised iron, plastic, ply wood and aluminium sheet were determined. The average dimensions of sal seed was increased with increase in moisture content ranging from 6.38 to 21.95% (d.b.). The unit seed mass was increased from 0.916 to 1.54 g with the increased in moisture content from 6.38 to 21.95% (d.b.). In the same moisture ranges, bulk density, true density and porosity were increased from 349.46 to 371 kg/m^3, 807.9 to 963.5 kg/m^3 and 56.74 to 62.24%, respectively. The coefficient of friction was increased linearly with increase in sal seed moisture content on four different surfaces namely ply wood, plastic, aluminium and galvanised iron sheet.

Key words: Sal seed, physical properties, moisture content, coefficient of friction

1. Introduction

Sal *(Shorea robusta)* is one of the important timber and non-timber plants of India. It is known for heavy or tough wood. It is widely distributed in tropical regions of India. Sal forest covers around 10 million hector in India. The report shows that sal seeds as potential non-timber forest product for enterprise development in India. It is a semi-evergreen tree and grows upto 50 m height. Apart from timber sal plant also play an important role for its seed. Sal seeds are harvested in the month of last week of May upto third week of June [1]. Sal seed consist of 64.4% kernel and 33.6% of shell. Sal seed primarily processed for extraction of its oil. It contain around 34% of oil [2]. It is important role in food, non-food and pharmaceutical industries based industries [3]. It can be used for production of cocoa based products. Recently sal seed identified as a source for vegetable based bio-diesel production [4]. Due to the lack of the technology these seeds are underutilize and very low cost in market.

Various researchers reported that design of post-harvest processing equipment depends on physical and mechanical properties of agricultural products [5-9]. The physical properties of agricultural products are necessary for designing and development of equipment for cleaning, grading, shorting, de-hulling or decorticating, oil extraction, storage and transportation [10], and also for assessing the product quality for the products. For this process, understanding of physical properties of sal seeds play crucial role in development of post-harvest processing equipment. These properties for sal seeds have not been reported in the literatures. Hence the aim of this research was to determine the effect of moisture content on physical properties of sal seed. Various parameters were determined namely, length, width, arithmetic mean diameter, geometric mean diameter, aspect ratio, surface area, bulk density, true density, porosity, angle of repose and coefficient of friction on various surfaces namely, galvanised iron, ply wood, plastic and aluminium sheet in the moisture content range from 6.38 to 21.95 % (d.b).

2. Materials and methods

2.1 Sample

Sal seeds were procured from the local areas of Rourkela, Orissa, India for this investigation. The samples were cleaned manually to remove the immature, infected, dust, stone, dirt, unwanted material and small seeds. The cleaned and graded samples were sundried and packed in air tight aluminium container. Moisture content is a useful information to conduct the experiment and also in the drying process [11]. The initial moisture content of seeds were determined by standard hot air oven method at 105$\pm$ 1°C for 24 h [12].

2.2 Sample preparation

Sal seeds were conditioned with a calculated amount of water by as per the procedure described by Pradhan et al, (9) and moistened to raise their initial moisture content to desire levels. All the physical properties were determined at moisture range of 6.38%, 10.49%, 13.63%, 17.63% and 21.95% [9, 13, 14].

2.3 Physical properties of sal sample

Samples of one hundred seeds were randomly selected from the bulk of the each conditioned sample. Dimensional properties like length, and width of the sal seeds were measured with a digital Vernier calliper with the accuracy of $\pm$0.01 mm The unit seed mass (g) was measured by using electronic weighing balance (Wensor ISO 9001: 2000 certified, India) with accuracy of $\pm$0.001 g. The average diameter of sample were calculated by using the arithmetic mean diameter, D_a and geometric mean diameter, D_g of seeds were determined standard methods [15-19].

Sphericity, (φ) seed was calculated based on the isoperimetric properties of the sphere. The higher the sphericity of the seed, the closer is its shape to a sphere [20, 21]. Aspect ratio, *(Ra)* and surface area, (S, mm^2) of seeds was calculated by standard methods [11, 22].

The bulk density (ρ_b), true density (ρ_t) and porosity (ε) of the bulk seed was calculated as per standard methods [11, 23]. The coefficient of friction was calculated as the tangent of the angle measured and was determined by method described by other researchers [23-26].

(a) **(b)**

Figure.1 Representation of two major dimensions of sal seed; length (a), width (b).

3. Results and discussion

Table 1 shows some dimensional properties of sal seed at its initial moisture content (10.49%, d.b). The average length (major axis) and width (minor axis) of the sal seeds was found to be 24.9±2.6 mm and 12.9±1.01 mm, respectively. The result shows that the length and width of sal seed was lesser than *Jatropha curcas* [27, 28] and higher than the peanut and kernel [29]. Various researcher reported that axial dimensions are very important for determine the aperture size and other machine parameters [28, 30]. The average arithmetic mean diameter and geometric mean diameter were also calculated as 23.6±1.5 mm and 19.3±1.1 mm, respectively.

The principle dimension such as length *(L)* and width *(W)* shows the linear tendency which is increased with increase in the moisture content from 6.38 to 21.95%, d.b (Fig.2). The dimensional axis were increase from 24.5 to 25.12 mm, and 12.76 to 13.61 mm for length and width for sal seeds, respectively. The linear increased in seed dimensions were reported for karingda seeds [31] and squash seeds [7]. The variation of moisture content (M_c) and principle dimensions was represented by linear equations as follows:

$$L = 0.0976\text{Mc} + 23.833 \qquad (R^2 = 0.958)$$

$$W = 0.0558\text{Mc} + 12.369 \qquad (R^2 = 0.958)$$

Table 1: Physical properties of sal seed at initial moisture content (10.49%, d.b).

Physical properties	N	Mean	Max	Min	SD
Principal dimensions, mm					
Length, *L*	100	24.9	33.1	21.2	2.6
Width, *W*	100	12.9	15.4	10.9	1.01
Average diameter, mm					
Arithmetic mean diameter, *Da*	100	23.6	23.6	16.7	1.5
Geometric mean diameter, *Dg*	100	19.3	19.3	14	1.1

- N is the number of observation, SD, Standard deviation.

The average diameter was calculated by arithmetic mean diameter *(Da)* and geometric mean diameter (*Dg)* were increased with increase in the moisture content as principal dimensions. The increase in principal dimensions and average diameter could be attributed to the expansion of the seeds as a result of moisture absorption in the intracellular spaces inside the seeds [32]. The relationship between the moisture content (M_c) and average diameter of sal seeds was obtained as follows:

$$Da = 0.00767\text{Mc} + 18.101 \qquad (R^2 = 0.980)$$

$$Dg = 0.0671\text{Mc} + 15.35 \qquad (\text{R}^2 = 0.990)$$

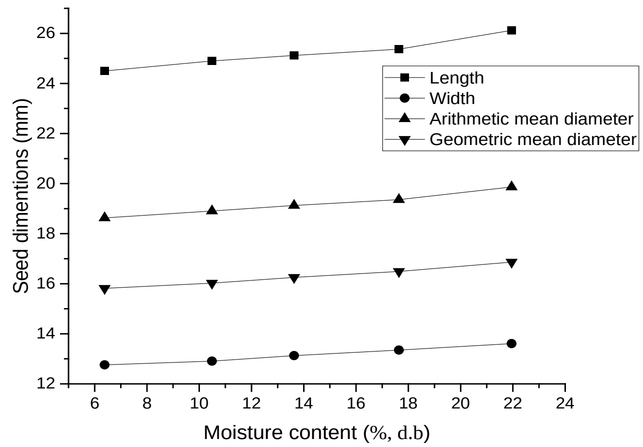

Figure 2: Effect of moisture content (d.b) on dimensions of sal seeds.

The sphericity of sal seed increased from 0.747 to 0.754, when the moisture content increased from 6.38 to 21.95% (d.b). Similar trend was reported for hemp seeds [33] and caper seeds [34]. Researcher reported that grain is spherical when the sphericity value is more than 0.80 and 0.70 [15, 21]. In this experiment sal seed determined as spherical in shape and it helps in calculation of surface area of the sal seeds. The linear equation for sphericity and moisture content *(M_c)* of sal seed can be formulated to be:

$$\varphi = 0.0005\text{Mc} + 0.7422 \qquad (\text{R}^2 = 0.850)$$

Aspect ratio *(Ap)* is the ratio of width and length in percentage which was increased with increase in moisture content. The positive linear relationship between the moisture content and aspect ratio as follows:

$$Ap = 0.0671\text{Mc} + 51.496 \qquad (\text{R}^2 = 0.9)$$

The variation of surface area *(S)* with increase in moisture content as shown in fig 3c. The surface area of sal seed increase linearly from 785.42 to 893.16 mm^2 when the moisture content increased from 6.38 to 21.95% (d.b). This property plays an important role to determine the projected area of irregular shaped objects moving in turbulent air stream and helps in cleaner and separator. Similar result has been reported for guar seeds [35]. The relation between surface area and moisture content *(M_c)* can be expressed mathematically as follows:

$$\text{Surface area} = 6.879\text{Mc} + 737.25 \qquad (\text{R}^2 = 0.989)$$

Unit seed mass *(g)* of sal seeds increased linearly from 0.916 to 1.54 g with increase in the moisture content from 6.38 to 21.95% (d.b) shown in fig 3d. The increase in seed mass with increase in seed moisture has been reported for barbunia beans. Various researcher reported that moisture dependent on mass of the agricultural material [37, 38]. The relation between the unit seed mass and moisture content *(M_c)* represented as:

$$\text{Unit seed mass} = 0.04\text{Mc} + 0.6869 \qquad (\text{R}^2 = 0.987)$$

The bulk density (kg/m^3) of sal seeds varied from 349.46 to 371 kg/m^3 and it is increased with the increase in the moisture content (Fig.4). The increase in bulk density with the moisture content is due to absorption of moisture compared to volumetric expansion of sal seeds. True density also increased with the increase in moisture content from 6.38 to 21.95% (d.b) and it might be attributed to the relatively lower true volume compared to the corresponding mass of the sal seed attained due to adsorption of moisture. Similar increasing trend has been reported for sunflower seeds [39]. This property can be used for separate seeds from lighter particles or foreign material. The following linear equation was used to describe the relationship between bulk density and true density with moisture content *(M_c)*.

$$\text{Bulk density} = 1.1153\,\text{Mc} + 346.22 \qquad (R^2 = 0.732)$$

$$\text{True density} = 9.4453\text{Mc} + 766.43 \qquad (R^2 = 0.898)$$

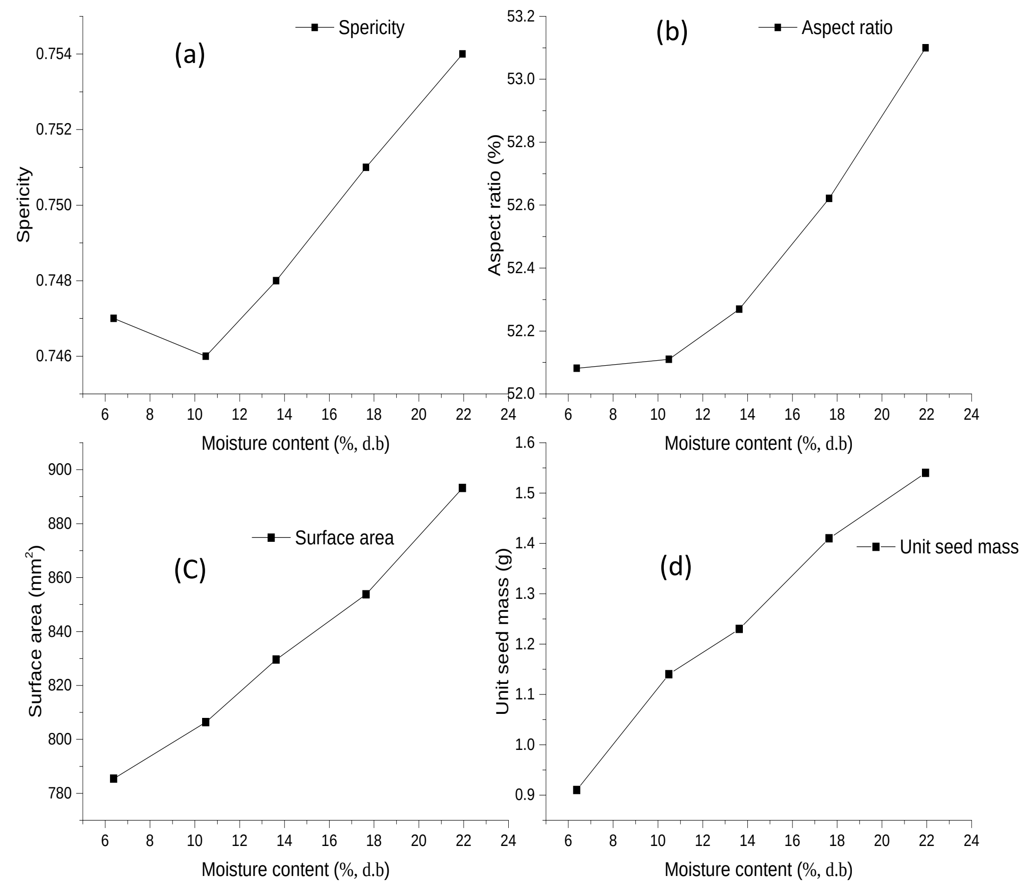

Figure 3: Effect of moisture content on (a) sphericity, (b) Aspect ratio, (c) Surface area and (d) unit seed mass of sal seed.

It was observed that porosity was increased from 56.74 to 62.24% when the moisture content was increased from 6.38 to 21.95% (d.b) (Fig 4). Similar result was reported for arecant kernels [40]. The relation between moisture content *(M_c)* and porosity was described mathematically as follows:

$$\text{Porosity} = 0.3513 + 54.652 \qquad (R^2 = 0.996)$$

The coefficient of friction of sal seeds against four different surface, namely aluminium, plastic, ply wood and galvanised iron are presented graphically in fig 5. It was observed that coefficient of friction were increased with increase in moisture content from 6.38 to 21.95% (d.b) for all the contact surfaces. The reason for increased coefficient of friction may be owing to water present in the seed offering a cohesive force on the surface of contact.

Similar trend was observed for popcorn kernels [41]. The highest coefficient of friction was observed for aluminium sheet at 21.95% (d.b) moisture content and lowest for plastic sheet at 6.38% (d.b) moisture content.

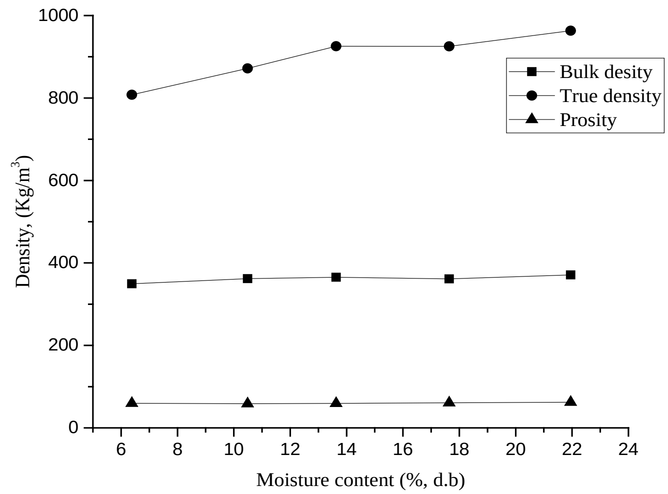

Figure 4: Variation of bulk density, true density and porosity of sal seed with moisture content (d.b).

The least coefficient of friction due to the smoother and highly polished surface of the plastic sheet than the other materials. The coefficient of friction affect the design of the post-harvest processing equipment and these four common materials were used for transportation and storage of agricultural materials. The linear equation between the coefficient of friction and moisture content *(M_c)* on aluminium, plastic, ply wood and galvanised sheet as follows:

$$\text{Aluminium} = 0.0078\text{Mc} + 0.2643 \qquad (R^2 = 0.986)$$

$$\text{Plastic} = 0.0052\text{Mc} + 0.2907 \qquad (R^2 = 0.975)$$

$$\text{Ply wood} = 0.0104\text{Mc} + 0.3289 \qquad (R^2 = 0.856)$$

$$\text{Galavanised iron} = 0.0069\text{Mc} + 0.3289 \qquad (R^2 = 0.726)$$

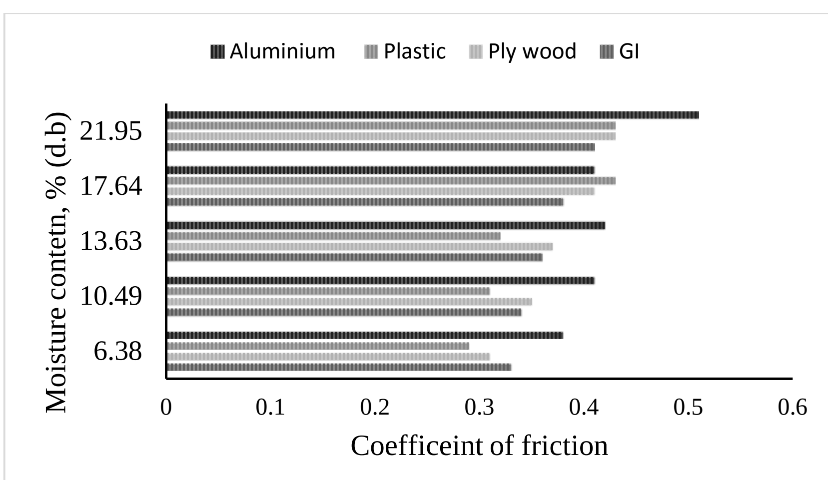

Figure 5: Effect of moisture content (d.b) on coefficient of friction of sal seed against various surfaces.

4. Conclusion

The following conclusion was obtained from the investigation on effect of moisture on physical properties of sal seeds in the moisture content ranging from 6.38% to 21.95% (d.b). The average dimensions were increased with the increase in the moisture content. The average dimension such as length, width, arithmetic mean diameter and geometric mean diameter ranged from 24.5 to 25.12, 12.76 to 13.61, 18.63 to 19.86, and 15.82 to 16.87 mm respectively. Sphericity, aspect ratio and surface area were found to increase from 0.747 to o.754, 52.08 to 53.1% and 785.42 to 893.16 mm^2 respectively, in the moisture range of 6.38% to 21.95% (d.b). In the same moisture content bulk density, true density and porosity were increased from 349.46 to 371 kg/m^3, 807.9 to 963.5 kg/m^3 and 56.74 to 62.24% with the increase in moisture content. The coefficient of friction, depending on friction surface, it was increased linearly with the increase in moisture content, namely aluminium sheet (0.38 to 0.51), plastic (0.29 to 0.43) ply wood (0.31 to 0.43) and galvanised iron (0.33 to 41) as moisture content increased from 6.38% to 21.95% (d.b). These properties help to determine the efficiency of agricultural processing machine and also development of post-harvest processing machine.

Reference

1. Patnaik, S., 2015, “Non Timber Forest Product, Enterprise and Forest Governance”. *Center for Peoples Forestry*
2. Singh, V., Soni, A., Kumar, S., and Singh, R., 2014, “Pyrolysis of sal seed to liquid product”. *Bioresource technology* 151:432-5
3. Naikodi, M.A.R,, Nagaiah, K., and Waheed, M., 2012, “Phytochemical Standardization of Oleo Resin of Shorea robusta Gaertn *(Dipterocarpaceae)* with modern analytical technique”. *International Journal of Phytomedicine* 4:503
4. Chhibber, V., Joshi, H.C., and Saxena. S.K., 2012, “Sal *(Shorea Robusta)*, an Environmentfriendly and Ecofriendly Alternative Vegetable Oil Fuel in comparison to diesel oil”. *Advances in Pure and Applied Chemistry* 1:36-9
5. Konak, M., Carman, K., and Aydin, C., 2002, “PH—Postharvest Technology: Physical properties of chick pea seeds”. *Biosystems Engineering* 82:73-8
6. Nikoobin, M., Mirdavardoost, F., Kashaninejad, M., and Soltani, A., 2009, “Moisture-dependent physical properties of chickpea seeds”. *Journal of Food Process Engineering* 32:544-64
7. Paksoy, M., and Aydin, C., 2004, “Some physical properties of edible squash *(Cucurbita pepo L.)* seeds”. *Journal of Food Engineering* 65:225-31
8. Olajide, J., and Igbeka, J., 2003, “Some physical properties of groundnut kernels”. *Journal of Food Engineering* 58:201-4
9. Pradhan, R.C., Naik, S.N., Bhatnagar, N. and Vijay, V.K., 2009, “Moisture-dependent physical properties of jatropha fruit”. *Industrial crops and products*, *29*(2), pp.341-347.
10. Sahay, K., and Singh, K., 2004, “Unit operations of agricultural processing”. Vikas Publishing House PVT LTD
11. Said, P.P., and Pradhan, R.C., 2013, “Moisture dependent physical properties of *Lagenaria siceraria* seed”. *International Journal of Agricultural and Biological Engineering* 6:111-20
12. Horwitz, W., 2000, “Official methods of analysis of AOAC International”, AOAC international
13. Yalçın, İ., 2007, “Physical properties of cowpea *(Vigna sinensis L.)* seed”. *Journal of Food Engineering* 79:57-62
14. Taghi Gharibzahedi, S.M., Mousavi, S.M., and Ghahderijani, M., 2011, “A survey on moisture-dependent physical properties of castor seed *(Ricinus communis L.)”*. *Australian Journal of Crop Science*, 5:1-7
15. Garnayak, D., Pradhan, R., Naik, S., and Bhatnagar, N., 2008, “Moisture-dependent physical properties of jatropha seed *(Jatropha curcas L.)”*. *Industrial crops and products* 27:123-9
16. Burubai, W., Akor, A,, Igoni, A., and Puyate, Y., 2007, “Some physical properties of African nutmeg (*Monodora myristica)”*. *International Agrophysics* 21:123
17. Dash, A., Pradhan, R., Das, L., and Naik, S., 2008, “Some physical properties of simarouba fruit and kernel”. *International Agrophysics* 22:111
18. Pliestic, S., Dobricevic, N,, Filipovic, D., and Gospodaric, Z., 2006, “Physical properties of filbert nut and kernel”. *Biosystems engineering* 93:173-8

19. Kingsly, A., Singh, D., Manikantan, M., and Jain, R., 2006, “Moisture dependent physical properties of dried pomegranate seeds *(Anardana)*”. *Journal of Food Engineering* 75:492-6
20. Karaj, S,. and Müller, J., 2010, “Determination of physical, mechanical and chemical properties of seeds and kernels of Jatropha curcas L”. *Industrial crops and products* 32:129-38
21. Pradhan, R. C., S. N. Naik, N. Bhatnagar, and S. K. Swain, 2008, “Moisture-dependent physical properties of Karanja *(Pongamia pinnata)* kernel”. *Industrial Crops and Products* 28: 155-161.
22. Wang, H., and Ng, T., 2000, “Lagenin, a novel ribosome-inactivating protein with ribonucleolytic activity from bottle gourd *(Lagenaria siceraria)* seeds”. *Life Sciences* 67:2631-8
23. Altuntaş E., Özgöz, E., and Taşer, Ö,F., 2005, “Some physical properties of fenugreek *(Trigonella foenum-graceum L.)* seeds”. *Journal of Food Engineering* 71:37-43
24. Altuntas, E., and Özkan, Y., 2008, “Physical and mechanical properties of some walnut *(Juglans regia L.)* cultivars”. *International Journal of Food Engineering* 4
25. Tunde, A.T., and Akintunde, B., 2004, “Some physical properties of sesame seed”. *Biosystems Engineering* 88:127-9
26. l-Mahasneh, M.A., and Rababah, T.M., 2007, “Effect of moisture content on some physical properties of green wheat”. *Journal of Food Engineering* 79:1467-73
27. Sirisomboon, P., Kitchaiya, P., Pholpho, T., and Mahuttanyavanitch, W., 2007, “Physical and mechanical properties of *Jatropha curcas L.* fruits, nuts and kernels”. *Biosystems Engineering* 97:201-7
28. Pradhan, R.C., Meda, V., Naik, S.N. and Tabil, L., 2010, “Physical properties of Canadian grown flaxseed in relation to its processing”. *International Journal of Food Properties*, *13*(4):732-743.
29. Aydin, C., 2007, “Some engineering properties of peanut and kernel”. *Journal of Food Engineering*, 79:810-6
30. Mohsenin, N.N., 1970, “Physical properties of plant and animial materials”. Vol. 1. Structure, physical characterisitics and mechanical properties. “Physical properties of plant and animial materials”. *Vol. 1. Structure, physical characterisitics and mechanical properties.* 1
31. Suthar, S, and Das, S., 1996, “Some physical properties of karingda *[Citrullus lanatus (Thumb) Mansf]* seeds”. *Journal of Agricultural Engineering Research* 65:15-22
32. Sologubik, C., Campañone, L., Pagano, A., and Gely, M., 2013, “Effect of moisture content on some physical properties of barley”. *Industrial Crops and Products* 43:762-7
33. Sacilik, K., Öztürk, R., and Keskin, R., 2003, “Some physical properties of hemp seed”. *Biosystems Engineering* 86:191-8
34. Dursun, E., and Dursun, I., 2005, “Some physical properties of caper seed”. *Biosystems Engineering* 92:237-45
35. Vishwakarma, R.K., Shivhare, U,S., and Nanda, S.K., 2012, “Physical properties of guar seeds”. *Food and Bioprocess Technology* 5:1364-71
36. Eşref, I., and Halil, Ü., 2007, “Moisture-dependent physical properties of white speckled red kidney bean grains”. *Journal of Food Engineering* 82:209-16
37. Mwithiga, G., and Sifuna, M.M., 2006, “Effect of moisture content on the physical properties of three varieties of sorghum seeds”. *Journal of food engineering* 75:480-6
38. Gupta, R., and Das, S., 1997, “Physical properties of sunflower seeds”. *Journal of Agricultural Engineering Research* 66:1-8
39. Kaleemullah, S., and Gunasekar, J.J., 2002, “PH—Postharvest Technology: Moisture-dependent Physical Properties of Arecanut Kernels”. *Biosystems Engineering* 82:331-8
40. Karababa, E., 2006, “Physical properties of popcorn kernels”. *Journal of Food Engineering* 72:100-7

Authors Biography

Shashikumar C is presently doing Master of Technology (Research) in Food Process Engineering, Department of Food Process Engineering, National Institute of Technology, Rourkela, Odisha, India. He has completed the Bachelor of Technology in Food Science and technology at University of Agricultural Science, Bangalore, Karnataka, India. He has done the research project and in plant training at United Spirts Ltd, Bangalore, Karnataka. He has completed the one year quality executive and food safety auditor post at Max Hypermarket Ltd. Bangalore, Karnataka. He has published the 2 research papers at International Journals. He has participated in International and National conference and seminars. He is very interested in developing the food and bio processing technology.

Rama Chandra Pradhan is an Assistant Professor in the Department of Food Process Engineering at the National Institute of Technology, Rourkela, Odisha, India. He earned B. Tech. in Agricultural Engineering from College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, India, Masters in Post Harvest Engineering from Indian Institute of Technology, Kharagpur and PhD in Post Harvest Technology from Indian Institute of Technology, Delhi. Dr Pradhan has received Jawaharlal Nehru Award for Outstanding Doctoral Thesis Research-2102 by Indian Council of Agricultural Research, New Delhi. He has published more than 25 journal papers in peer-reviewed journals and conferences papers. Dr Pradhan is handling research projects funded by SERB, SEED, Department of Science and Technology, ICAR, New Delhi. His research interests include properties of foods, design and development of equipment, membrane filtration, food process engineering and value addition to agricultural produces. He is a member of ISAE and IE(India).

Dr. Sabyasachi Mishra is an Assistant Professor in the Department of Food Process Engineering at the National Institute of Technology (NIT), Rourkela, Odisha, India. His PhD is in Food and Bioprocess Engineering from University of Saskatchewan, Canada. He earned his Bachelors in Agricultural Engineering from Orissa University of Agriculture and Technology, India and Masters in Post Harvest Food Engineering from Indian Institute of Technology, Kharagpur. He has more than eight years of teaching and research experience including post-doctoral fellowships in Canada and has published more than 25 research articles and chapters in international journals and conferences of higher repute. He is presently handling many externally sponsored research projects funded by ICAR, SEED-DST and Ministry of Food Processing Industry, Govt. of India. His research interests is in food process engineering, food safety & quality control and value addition. He is a member of ASABE (USA), CSBE (Canada) and ISAE (India).