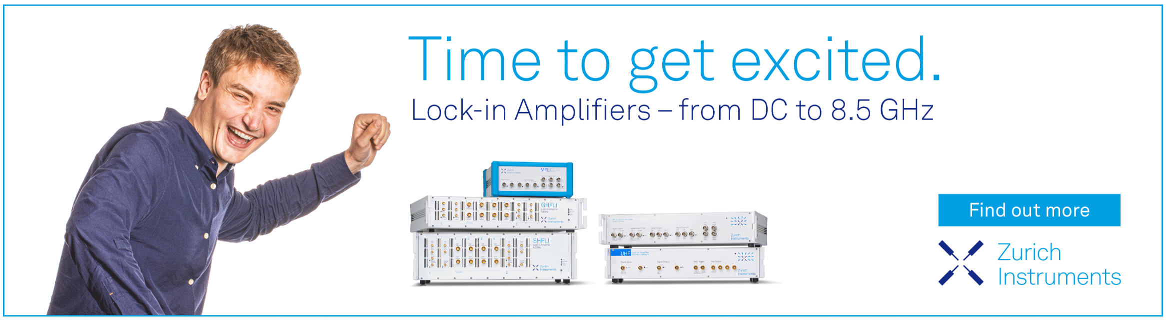
AIP Conference Proceedings

RESEARCH ARTICLE | APRIL 27 2023

The crispness of cassava crisps with random shape by compression test

Dara Ginanti; Farid Triawan ✉; Kushendarsyah Saptaji; ... et. al

AIP Conference Proceedings 2646, 050013 (2023)
https://doi.org/10.1063/5.0113444



The Crispness of Cassava Crisps with Random Shape by Compression Test

Dara Ginanti[1, 2], Farid Triawan[1, a)], Kushendarsyah Saptaji[1] and Lydia Anggraini[3]

[1]*Department of Mechanical Engineering, Faculty of Engineering and Technology, Sampoerna University, Jakarta, Indonesia*
[2]*Department of Aerospace and Mechanical Engineering, the University of Arizona, Tucson, AZ, USA*
[3]*Study Program of Mechanical Engineering, Faculty of Engineering, President University, Bekasi, Indonesia*

[a)] Corresponding author: farid.triawan@sampoernauniversity.ac.id

Abstract. The most popular term that is used to represent brittleness texture of dry food is its crispness. Based on the previous studies, the crispness becomes the most essential quality of crisps that define the enjoyment when eating the food. Despite its importance, crispness is still determined qualitatively by human sensory perception which is very ambiguous. Thus, a measurement technique to quantitatively define the crispness level of dry food is needed. This study introduces a measurement technique by means of compression test to quantitatively determine the crispness of dry food with random shapes. The evaluated specimen is cassava crisps with three different thicknesses: 1, 2, and 3 mm. The parameters utilized to express the crispness level are strain energy and jaggedness obtained from the load-displacement curve. According to the evaluation, the results show that the 1 and 2 mm specimens are 29.2 and 16.5% crispier than the thickest specimen of 3 mm.

INTRODUCTION

Food is part of a human basic need that is regularly consumed to fulfil the body's nutrition and survive. Besides the nutrition inside the foods, the testiness is also being examined for the development of the food industry. When dealing with crisps food, the crispness becomes the most essential quality that defines the enjoyment when biting or chewing the food [1]. In addition, from a study by Zampini and Spence, the result says that the crispness level is affecting the addiction to potato crisps more than the taste of the crisps [2]. Therefore, the quality of crispness is an important parameter in the dry food industry. Nevertheless, there is still no certain measurement standard that can define the level of crispness of dry foods yet.

An ambiguity among human perceptions toward crispness still exists in today’s life. People may have their own perspective on whether the food can be said to be crispy or not. Usually, crispness is evaluated qualitatively from human perception toward the sensory properties of the food. If the sound of the biting is loud, then, the food is said to be crispy [1,3]. This method is found to be ineffective and ambiguous. Thus, the need to find an effective method to quantitatively define the crispness level of dry food does exist. The previous works reported that the crispness measurement methods could be varied starting from the sensory, puncture, and compression tests [3-6]. The most recent study by Triawan et al., found that the compressive strain energy from the stress-strain curve of compression test can be utilized to define the crispness level of potato crisp [6]. However, the study only used a potato crisp with regular shape, and the test was done by a single specimen. Since most of the crisp foods, including potato and cassava crisps, usually have a random (irregular) shape, thus a further investigation to overcome this issue is needed.

Proceedings of the Symposium on Advance of Sustainable Engineering 2021 (SIMASE 2021)
AIP Conf. Proc. 2646, 050013-1–050013-5; https://doi.org/10.1063/5.0113444
Published by AIP Publishing. 978-0-7354-4426-3/$30.00

In this work, the crispness level of cassava crisps with different thicknesses and random shape is evaluated by compression test method. The compression test is chosen since it could simulate human-biting behavior in sensing the crispness level. This study would be essential for the development of the food industry, especially for the food developer in Indonesia. Understanding on the quality of dry food by modifying its crispness property may serve the needs of consumers from all range of ages. There are many dry foods that cannot be enjoyed and eaten by the elder people. Especially for the crispy foods, the elder people who are having a low strength in their teeth are restricted to eat these products. Quantifying the level of crispness will help these people to find their suitable crispness level. Then, the expected result is to make crispy foods of which its crispness level could be adjusted, thus it could be enjoyed by all people.

METHODOLOGY

Specimen Preparation

This work used the cassava crisps as the dry food. The cassava crisps specimen was made and prepared following the homemade recipe. The cassava crisp was chosen because its crispness level could be modified by changing its thickness. In this work, the specimens were prepared with three different thicknesses, 1, 2, and 3 mm. All the utensils used in the cooking process were the same tools as those used by the home industry, such as knife and slicer. This method was applied because it would be able to mimic the typical production processes applied in the home industry. After the deep-frying process [7], all crisp specimens were placed in a vacuum container to avoid any effect from the moisture.

Compression Test Procedure

The specimens were tested by compression test method using the Tensilon Universal Testing Machine RTF-2350. The testing set-up is shown in Fig. 1. A container made of transparent acrylic was used to hold the crisps specimens, therefore multiple number of specimens could be tested in one time. The purpose is to neglect the size effect caused by the random shape of the crisp. The acrylic container is installed on the machine and clamped to the bottom plate so that it cannot move when the top jig is compressing the crisp specimens. The inner diameter of the container is 138 mm, while the outer diameter of 150 mm. It has a height of 185 mm and has a maximum capacity of 2250 ml. Moreover, the clamping was made through several processes from welding, drilling, and turning. The size was customized and made to fit the dimension of the acrylic container.

To perform the multi-specimen compression test, 6750 g weight of cassava crisps were prepared. The crisps were then divided into three groups based on its thickness. Each group contains 2250 g which was then divided per 250 g to fill in the container. Then, the compression test was carried out until all the specimens crushed and densified.

Referring to the previous works using compression tests [6,8,9], the machine was operated at the crosshead speed of 10 mm/s. Considering the cassava crisp is a brittle material [7,10], thus speed is considered not to give any strain rate dependency effect. The overload value of loadcell was set to be 1000 N. The measured load-displacement data was then cut until 460 N considering the maximum value of human biting ability [11].

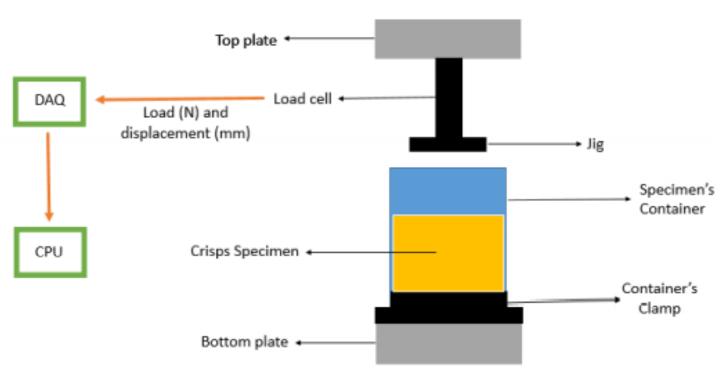


FIGURE 1. Schematics of the set-up

Data Analysis Procedure

The typical load and displacement data measured from the compression test is shown in Fig. 2. The load is plotted only until the highest biting human ability, which 460 N. Then, the curve is transformed into stress and strain curve as shown in Fig. 3. Using these curves, the compressive strain energy and jaggedness parameters were investigated to quantitatively define the crispness of the cassava crisp specimens.

The first parameter that was evaluated is the jaggedness of the load-displacement curves. The jaggedness is related to the crispness as reported by Tunick et al. [4] and Peleg [12]. The jaggedness is defined as the jagged level of the alternating load during compression test. The alternating load is interpreted as the jagged value that more or less than the average value. So, prior to the jaggedness calculation, the raw data of load and displacement was subtracted by its average value for every displacement increment. In Fig. 2, the blue line curve shows the raw data, and the red line curve shows the average value. The blue line curve was first subtracted by the red line curve; thus the alternating load could be obtained. This alternating load could be used as the indication of how many fracture incident happen during the compression test [13,14].

In this work, the jaggedness value was analyzed by utilizing the standard-deviation method [13]. Thus, after obtaining the value of the alternating load, the standard deviation of the data is calculated. Finally, the jaggedness value is formed into a range of 0 to 1 in which 1 is the most jagged and 0 is no jaggedness at all. The equation that is used to evaluate the jaggedness is shown in Equation 1.

$$Jaggedness = 1 - \frac{1}{(1 - stdev)} \quad (1)$$

In parallel, the compressive strain energy was analyzed from the area under the stress-strain curve as shown in Fig. 3. This area under the curve indicates the total energy needed to deform the specimen until fracture or crushed [6,15]. In other words, how difficult the specimen to undergo deformation and then fracture could be indicated by the strain energy value. Triawan et al., reported by a single specimen test, the compressive strain energy could precisely predict the difference in crispness level among potato crisp specimens which are treated under different moisture effect [6].

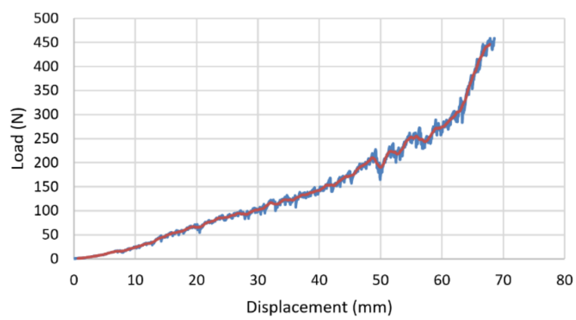


FIGURE 2. The typical load and displacement curve of the cassava crips measured compression test. The plot is cut until 460 N as it is the maximum load of human biting ability

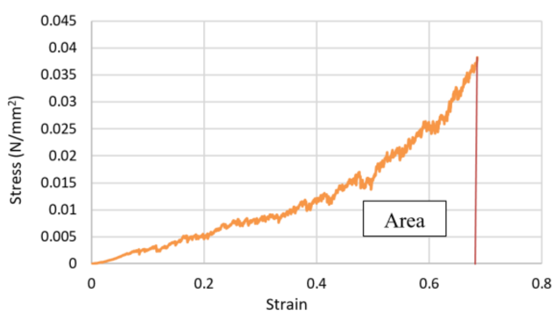


FIGURE 3. The stress-stress curve being utilized to determine the compressive strain energy as indicated by the area below the curve

RESULTS AND DISCUSSION

The mechanical parameters that are used to quantify the level of crispness are summarized in Table 1. The compressive strain energy values are obtained from the stress and strain curves of all specimens. The jaggedness is gained from the load and displacement curve, this parameter represents how many fracture events happen during the test. Here, event mean the fracture or breaking of the specimens. From this table, it can be observed that the thicker the thickness of the crisp specimens, the greater the compressive strain energy will be. On the other hand, the jaggedness values show the opposite tendency. The thinnest specimen experiences the most jagged load, while as the thickness increase, the jaggedness value also decreases.

By qualitatively analyzing the graph shown Fig. 4, all the three compression test results are showing some differences. Therefore, a deeper quantitative analysis is done. Now, if the value of the strain energy from all the three specimens is compared, the thinnest specimen is found to be 29.2% crispier than the thickest specimen, and then followed by the specimen of 2 mm thickness with 16.5% crispier. This means that the thinnest specimen is more fragile and require less strain energy to make it fractured. While about the jaggedness, the thinnest specimen is found to be 2.4% crispier, and followed by the 2 mm which is 0.6% crispier than the thickest one. This means that the specimen with 1 mm thickness experiences more fracture and break. This happens due to the brittle fracture behavior of the deep-fried cassava crisp [7]. In short, the thinnest specimen is the crispiest specimen among the whole specimens.

TABLE 1. Compression test result

Specimen Thickness	Strain Energy (GPa)	Jaggedness (Dimensionless)
1 mm	6.832	0.8937
2 mm	8.050	0.8777
3 mm	9.651	0.8724

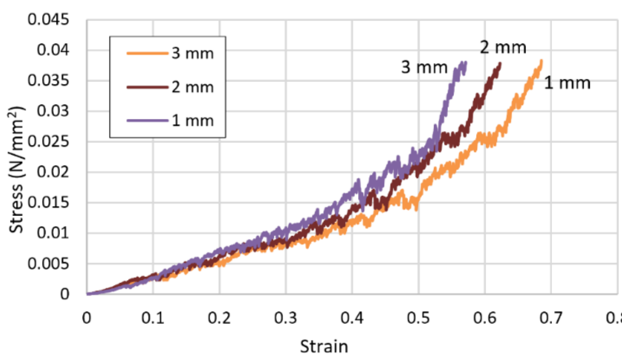


FIGURE 4. The comparison of stress-strain curves of the cassava crisp specimens with three different thicknesses

CONCLUSION

Crispness measurement of cassava crisps with three different thicknesses and random shape has been done successfully by compression test method. A special jig container is prepared to perform the test, therefore multiple number of specimens can be tested at the same time. From the test, the load and displacement curves as well as the stress and strain curves are utilized to calculate the jaggedness values and the compressive strain energy. The results show that this technique was able to quantitively determine the crispness value of the cassava crisp specimens which are cooked in a deep-frying method. It was revealed that the crispier the cassava crisps, the smaller the strain energy. Moreover, the crispier the cassava crisps, the more jagged the load-displacement curve. In other words, the more the crisp to experience fractures and breaks during compression load, the crispier the product will be. Based on the quantification results, it was found that the 1 and 2 mm cassava crisps are 29.2 and 16.5% crispier than the thickest specimen of 3 mm. This methodology can be used by the food industry to define and distinguish the crispness level of their dry food products.

ACKNOWLEDGEMENT

The authors are deeply grateful for the financial support from the internal research grant of CRCS Sampoerna University, and for the testing apparatus which was supported by Yogyakarta State University.

REFERENCES

1. Z. M. Vickers, Journal of Texture Studies **15**, 157 (1984).
2. M. Zampini and C. Spence, Journal of Sensory Studies **19**, 347 (2004).
3. S. Saklar, S. Ungan, and S. Katnas, Journal of Food Science **64**, 1015 (1999).
4. M. H. Tunick, C. I. Onwulata, A. E. Thomas, J. G. Phillips, S. Mukhopadhyay, S. Sheen, C. K. Liu, N. Latona, M. R. Pimentel, and P. H. Cooke, International Journal of Food Properties **16**, 949 (2013).
5. F. J. Rojo and J. F. V. Vincent, International Journal of Food Science and Technology **43**, 752 (2008).
6. F. Triawan, G. E. Aprilia, and K. Saptaji, Indonesian Journal of Computing, Engineering and Design (IJoCED) **3**, 106 (2021).
7. L. Hashim, A. A. Mat Ropi, A. S. Alikasturi, M. R. Anuar, N. Z. Safiei, I. I. Muhamad, Y. M. Mohd Jusoh, and S. Shaharuddin, Materials Today: Proceedings **31**, A85 (2020).
8. H. S. Kwak, S. S. Kim, Y. H. Chang, M. Saleh, and Y. Lee, Journal of Food Quality **2019**, (2019).
9. F. Triawan, E. Rachmawati, B. A. Budiman, D. W. Djamari, A. Saputro, and I. Arpi, Indonesian Journal of Science and Technology **6**, 543 (2021).
10. P. Chantaro, P. Chalermchaiwat, and T. Harnsilawat, RMUTP Research Journal **14**, 154 (2020).
11. S. Varga, S. Spalj, M. Lapter Varga, S. Anic Milosevic, S. Mestrovic, and M. Slaj, European Journal of Orthodontics **33**, 427 (2011).
12. M. Peleg, Journal of Texture Studies **25**, 403 (1994).
13. M. Peleg, Critical Reviews in Food Science and Nutrition **37**, 491 (1997).
14. A. Salvador, P. Varela, T. Sanz, and S. M. Fiszman, LWT - Food Science and Technology **42**, 763 (2009).
15. F. Triawan, G. C. Denatra, and D. W. Djamari, International Journal of Sustainable Transportation Technology **3**, 66 (2020).