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Mechanical Characterization of Crispness in Dry Foods via Multi Specimen Compression Testing

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Graphical Abstract

Highlights

- A multi-specimen uniaxial compression test was developed to quantitatively assess crispness in dry snack foods, correlating well with sensory rankings
- Thinner cassava chips (1 mm) showed the highest crispness, while thicker chips exhibited reduced crispness, demonstrating the effect of slice thickness on texture.
- The dried Sus cake demonstrated higher crispness metrics than the thinnest cassava chips, aligning with sensory perception, despite originating from a different food type.

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ABSTRACT

Texture is a critical quality attribute of dry snack foods, with crispness being especially important for consumer enjoyment. However, crispness is often judged subjectively by sensory evaluation, leading to ambiguity and inconsistency. This study develops a quantitative mechanical method to characterize crispness in dry foods using a multi-specimen uniaxial compression test that simulates human biting. Cassava chips (at three slice thicknesses) and a traditional dried Sus cake were tested in batches within a custom container under identical conditions. Statistical analysis (ANOVA) confirmed that these parameters notably differentiate samples (at $P < 0.20$ level) and correlate with sensory crispness rankings. The thinnest cassava chips (1 mm) exhibited the highest crispness (lowest energy and slope, highest jaggedness), whereas thicker chips were less crisp. Notably, the dried Sus cake, despite its different origin, showed higher crispness metrics than even the thinnest cassava chips, aligning with sensory perception. These results demonstrate that the proposed multi-specimen compression test can quantitatively distinguish crispness levels in foods of irregular shape. This study offers a qualitative data of crispiness on multi-specimen basis for specimen with random shapes by using the uniaxial compression test with two parallel plates. The key variables taken into account are the strain energy, mean slope of the stress-strain curve, and the jaggedness of the load-displacement curve.

1. Introduction

Crisp and crunchy textures are highly desirable qualities that contribute to the enjoyment of many snack foods [1]. Crispness in particular refers to a dry, brittle texture that produces a sharp sound upon biting. It is closely associated with product freshness and consumer appeal. Potato chips are favored worldwide as a snack partly due to their crispy texture. Despite its importance, there is no universal quantitative standard for crispness level [2, 3]. The terminology itself can be confusing – consumers sometimes interchange crispy and crunchy, even though technically crunchiness tends to imply a lower-pitched, less intense sound compared to crispness. Vickers (1983) found that crispness is strongly linked to the pleasantness of food biting sounds, highlighting its sensory significance [4]. However, traditional evaluation of crispness relies on human sensory panels, which are subjective and variable [5].

The crispness measurement, various instrumental approaches have been explored. One approach is acoustic analysis, where sound emitted during food fracture is recorded. Studies have shown that *crispy* foods produce more numerous and higher-intensity sound events than less crispy ones. Sanz et al. (2007) combined acoustic measurements with a penetration test and concluded that a higher number of sound events and greater sound pressure magnitude correlate with higher crispness [6]. Similarly, Salvador et al. (2009) used simultaneous sound and force measurements and found that products with more sound events and higher sound pressure levels are perceived as crisper [7]. Another common approach is single-specimen compression tests, where a flat probe crushes one piece at a time and parameters like force peak, number of fracture events, and work of fracture are recorded [8].

Many traditional methods test one specimen at a time under controlled geometry, which may not be applicable to non-uniform, randomly shaped foods like artisanal chips or snacks. In such cases, results from a single piece can vary widely and may not represent the batch’s overall texture [9, 10]. To address this, the present study introduces a multi-specimen compression test method, wherein multiple pieces are tested simultaneously to obtain a more representative measure of crispness. By averaging the response of many pieces in one compression, shape irregularities and piece-to-piece variability can be accounted for, yielding a robust crispness metric for the product as a whole. This study aims to evaluate the appropriateness of a bulk compression test—

where several samples are compressed concurrently—for measuring crispness, while also quantifying and comparing the crispness of two model products, namely cassava crisps at three different thickness levels and dried *Sus* cake, using mechanical parameters. Correlating mechanical indications with qualitative crispness ratings helps to evaluate the efficacy of the chosen test technique by identifying which mechanical characteristics most accurately reflect crispness. By establishing a scientific standard for crispness, this research can assist food engineers in objectively evaluating and designing product textures to meet consumer preferences.

2. Materials and Methods

2. 1 Samples and Preparation

Four dry food products were selected as test specimens: cassava crisps of three different thickness categories (representing high, medium, and low crispness levels) and a dried Sus cake (a traditional Indonesian semi-porous snack). All samples were obtained fresh and stored air-tight to preserve texture. The cassava crisps were prepared in-house from raw cassava tubers. A custom manual slicer tool with adjustable blade height was used to cut cassava slices of 1 mm, 2 mm, and 3 mm thickness. The slices were then deep-fried in vegetable oil under identical conditions to produce crisp chips. This yielded three groups of cassava chips: group 1 (1 mm thick, expected most crispy), group 2 (2 mm, moderately crispy), and group 3 (3 mm, least crispy). Each group's chips were cooled and sealed in airtight plastic containers (250 g per container) until testing, to prevent moisture uptake and staling. The traditional Sus cake (a dried meringue-like puff) was sourced from a local home industry and likewise stored in its original sealed packaging. No further size modification was done for the Sus cake; all pieces were roughly similar in size (approximately 3–4 cm diameter). Prior to testing, all specimens were inspected to ensure no cracks or damage; only intact pieces were used.

After frying, bulk sample quantities were prepared for the multi-specimen tests. For each cassava thickness group, approximately 750 g of chips (from the same batch) were collected, and for the *Sus* cake, about 600 g of product was available. These were subdivided into smaller portions for each test run. In preliminary trials, a sample mass of 250 g per test was found appropriate for cassava chips (filling the container to a consistent level without premature densification), while 200 g per test was used for the denser *Sus* cake. Thus, each cassava group yielded three test samples (250 g each × 3 = 750 g total), and the *Sus* cake yielded three samples (200 g × 3 = 600 g). Each of these samples was placed in identical containers and stored at room temperature (~25°C) for at least 24 h before testing to equilibrate. Each ID represents one container test and three replicates per group were tested (STP = very thin; SSD = medium; STB = very thick). The dried *Sus* cake samples (200 g each) were similarly tested thrice (IDs: SUS-01, 02, 03). Table 1 summarizes the specimen groups and nomenclature used for data logging.

Table 1. Sample Groups and Naming Convention for Cassava Crisps (All Samples of *Sus* Cake Were Treated as A Single Group)

Cassava Crisp Group	Thickness	Mass per Test	Sample IDs	Expected Texture
Group 1 (STP)	1 mm (thin)	250 g	STP-01, 02, 03	Very crispy (most brittle)
Group 2 (SSD)	2 mm (medium)	250 g	SSD-01, 02, 03	Moderately crispy
Group 3 (STB)	3 mm (thick)	250 g	STB-01, 02, 03	Least crispy (most crunchy)

2. 2 Compression Test Setup

A bulk compression test was designed to simulate the act of biting into a handful of pieces simultaneously. The test apparatus consisted of a cylindrical acrylic container to hold the sample pieces and a Universal Testing Machine (UTM) with flat parallel plates for compression. The transparent container had an inner diameter of 138 mm and height of 185 mm (volume ~2.25 L), providing enough space for the sample mass without overflowing (Figure 1). The container constrained the pieces laterally, preventing them from escaping sideways when crushed, and also minimized the influence of piece orientation by creating a consistent packed bed. The container keeps the pieces confined, ensuring uniform application of force. Moreover, the container was clamped firmly onto the UTM base to avoid movement during compression. Table 2 lists the container dimensions.

Figure 2 Acrylic Container Used as Specimen Holder for Multi-Sample Compression

Table 2. Dimensions of The Specimen Container (Acrylic Cylindrical Cup)

Container Dimension	
Inner diameter	138 mm
Outer diameter	150 mm
Height	185 mm
Material thickness	0.06 mm
Capacity	2250 ml

Compression tests were conducted on a Tensilon RTF-2350 Universal Testing Machine (A&D Co., Japan) equipped with flat stainless-steel plates (compression platens) as the upper and lower fixtures. The entire container filled with sample was placed on the bottom platen (Figure 3), and the crosshead was programmed to move downward, crushing the contents. Based on prior studies of crisp material compression and preliminary trials, a crosshead speed of 10 mm/min was selected (quasi-static load) to allow capturing multiple fracture events; an overload protection limit of 1000 N was set to stop the test if loads exceeded this threshold. The machine settings are summarized in Table 3. Each test continued until the sample was fully compressed (plate displacement reaching the container bottom or a dense compact, typically at ~70–80 mm displacement for cassava chips, ~50 mm for *Sus* cake). Force–displacement data were recorded at 1 kHz throughout the test via the machine's software.

(a) (b)

Figure 3 Compression test setup. The container (a) with sample is clamped on the UTM base, and the flat compression platen (b) descends to crush the pieces. This simulates a biting action on multiple pieces concurrently

Table 4 Compression machine parameters

Parameter	Setting
Instrument	A&D Tensilon RTF-2350 UTM (50 kN load cell)
Compression fixture	Flat parallel plates (rigid steel)
Crosshead speed	10 mm/min (constant)
Test termination	Auto-stop at 1000 N load or full compaction
Data acquisition rate	1000 Hz (force and displacement)
Test environment	Room temperature (~25°C), ambient humidity

Before each test, the prepared sample (250 g chips or 200 g cake) was gently poured into the container, filling it to a certain height (approximately 50–70 mm of loose chips, ~30 mm for

Sus cake). No pre-compression or tamping was done; the weight of the pieces themselves settled the packing. The top platen was then brought down to just touch the sample surface (establishing the zero reference for displacement). The compression was executed as a single continuous stroke. Each sample was tested three times (in separate containers) per group for replication. After each run, the force–displacement curve was saved for analysis.

2. 3 Data Analysis

The raw output of each compression test was a force–displacement curve characterized by multiple force peaks as the numerous pieces fractured. To derive meaningful crispness parameters, the raw data required further processing. The force F was converted to engineering stress σ using Equation 1 [11]:

$$\sigma = \frac{F}{A} \tag{1}$$

where A=1.50 × 104 mm² is the initial cross-sectional area of the sample bed. Displacement δ was converted to engineering strain ε using Equation 2 [12]:

$$\varepsilon = \frac{\delta}{h_0} \tag{2}$$

where h_0 is the initial height of the sample bed.

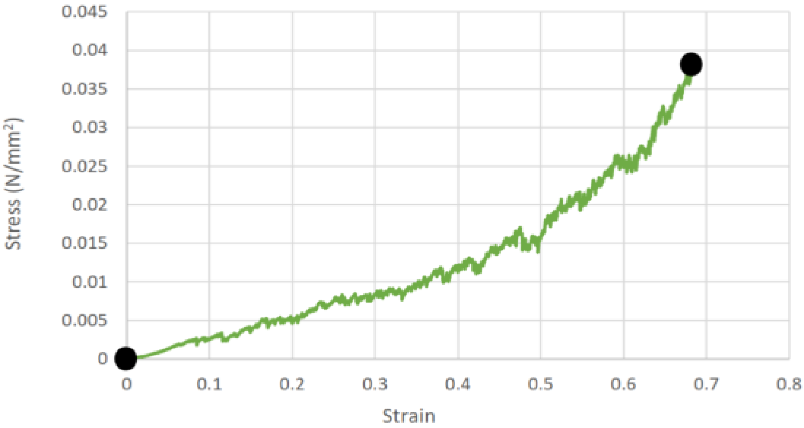


Figure 4 Stress–strain curve of a cassava crisp sample (1 mm thick)

This yielded a stress–strain curve for each test (Figure 4, green line). It is illustrated points used to calculate the average slope. The filled circles (●) mark the first and last significant load points, between which the slope is computed. A gentler slope indicates a crispier (less stiff) material. The average slope is $\frac{\Delta\sigma}{\Delta\varepsilon} = 6.317 \times 10^{-6} \frac{N}{mm^2}$ (very low), reflecting the brittleness of the thin cassava chip. The work of compression (or strain energy) was calculated by numerically integrating the stress–strain curve to determine the area under the curve up to the point of densification [13]. This value, expressed in N·mm/mm², represents the energy required to break down the sample structure, with lower energy indicating a crispier and more fragile product. Then, the average slope of the stress–strain curve was used as a proxy for material stiffness [14]. This was determined by connecting two characteristic points: the initial detectable increase in load and the point of densification. This slope reflects overall structural rigidity; lower values indicate less resistance to deformation, as expected in more brittle and crispy items [15]. Figure 4 illustrates the two selected points used for slope calculation in a sample. Finally, jaggedness was assessed to capture the oscillatory nature of the load–displacement curve, which results from sequential fractures. A jaggedness index was computed by applying a moving average filter (window size ~0.5 mm) to smooth the force signal, then calculating the standard deviation of the residual (i.e., the difference between raw and smoothed curves). A higher jaggedness index reflects more abrupt force drops and frequent cracking events, characteristic of crispy textures that break easily into fragments.

2. 4 Analysis of Variance (ANOVA)

All analyses were performed using MATLAB R2022a (MathWorks Inc.). Each parameter was averaged over the three replicates per sample group, and standard deviations were computed. To determine if the differences in parameters between sample groups were statistically significant, analysis of variance (ANOVA) tests were conducted. The relatively small sample size (n=3 per group) and inherent variability in such texture measurements, a significance level of 20% ($a = 0.20$) was used as a threshold in this exploratory study. A one-way ANOVA F-test was performed for each parameter across the four sample groups (1 mm, 2 mm, 3 mm cassava, and *Sus* cake). Subsequently, pairwise comparisons between groups were examined using post-hoc t-tests (with Bonferroni adjustment). The slightly relaxed significance criterion was chosen in light of known uncertainties: irregular shapes lead to non-uniform stress distribution, and differences in packing density (e.g., thin chips occupy more volume with voids than thick chips for the same mass) could introduce variability. These factors warranted a cautious interpretation of *P*-values.

The ANOVA F-test results for the three main parameters are summarized in Table 5. In each case, a *P*-value of 0.1858 (< 0.20) indicates a statistically significant difference among the groups under the chosen criterion. All statistical calculations were done using Minitab 19 (Minitab LLC) with $a = 0.20$. A relatively high significance level ($a = 0.20$) was selected due to the exploratory nature of the study and the goal of identifying potentially influential parameters for further investigation.

Table 5 ANOVA F-Test

Source of Variation	SS	df	MS	F	P-value	Fcrit
Between Groups	1.19917E-05	2	5.99584E-06	2.257346	0.185808	5.143253
Within Groups	1.59369E-05	6	2.65615E-06			
Total	2.79286E-05	8				

3. Results and Discussion

3. 1 Mechanical Behavior of Different Samples

All samples produced force–displacement curves typical of brittle, cellular foods: an initial elastic region, followed by a series of force drops as the structure fractured progressively, and finally a densification stage where fragments were compressed into a compact mass. Figure 5 shows representative load–displacement curves for (a) cassava crisps and (b) dried *Sus* cake. The thin cassava crisps (1 mm) exhibit many small force peaks and a low overall force, whereas the *Sus* cake shows a distinct initial peak and generally higher force levels before densification.

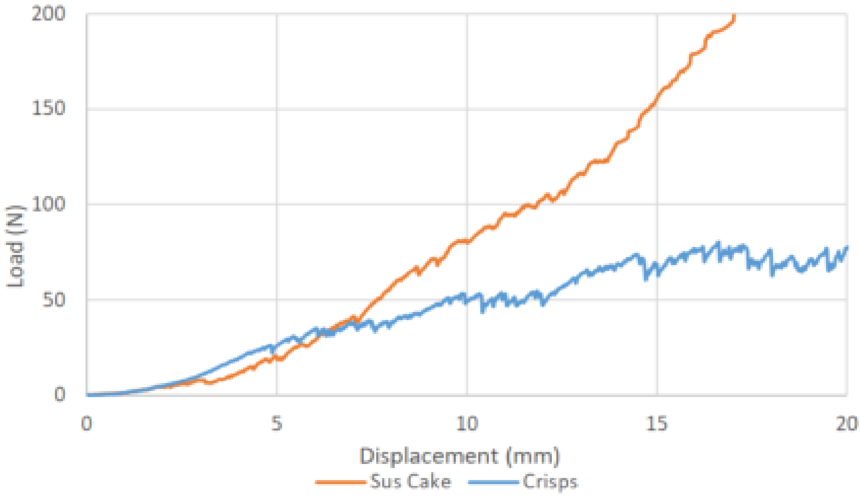


Figure 5 Load vs. Displacement Curve of Dried *Sus* Cake (a) Cassava crisps (1 mm vs. 3 mm thick) and (b) Dried *Sus* Cake

Clear trends are observed of the 1 mm cassava crisps have by far the lowest work of fracture and slope, and the highest jaggedness. As thickness increases, chips become less crisp – work and slope rise, jaggedness falls. The 3 mm chips required about double the energy to compress compared to 1 mm chips, indicating a much "harder" bite. Interestingly, the dried *Sus* cake behaves somewhat like an extremely porous crisp: it required very low energy and force to compress (comparable to or even less than the 1 mm chips) and had a highly jagged force profile. Quantitatively, the *Sus* cake's jaggedness index was ~0.83 N, slightly higher than the thin cassava chips (~0.80 N), suggesting it generated even more irregular force drops (likely due to its foam-like internal structure). These observations already imply that the *Sus* cake is extremely crispy – potentially crisper than any of the cassava chips, a result confirmed by statistical analysis.

3. 2 Statistical Analysis of Crispness Parameters

The one-way ANOVA F-tests (Table 6) show that for each parameter (work, slope, jaggedness), differences among the four sample types are significant at the 80%

confidence level (P-values 0.13–0.19). This suggests that one sample group is distinct from the others in each metric. The small sample size can interpret these results cautiously but proceed to pairwise comparisons. All three parameters, P < 0.20 indicating a significant effect of sample type. Thus, sample texture has a measurable impact on these metrics.

Table 6 ANOVA F-Test Results for Crispness Parameters (comparing all 4 sample groups)

Parameter	F *(df=3,8)*	P-value	Significance (@ 20%)
Work of fracture	2.26	0.186	Yes (P < 0.20)
Avg. slope	2.83	0.136	Yes
Jaggedness	2.96	0.127	Yes

To explore which specific differences drive these results, Table 7 (a-c) presents the pairwise *t*-test outcomes. The comparison crispness metrics between each pair of cassava chip groups and between cassava chips and *Sus* cake.

Table 7 Pairwise comparison (ANOVA *t*-test) results between sample groups (significant differences at *P* < 0.20 are bolded and n.s. = not significant at 20% level

(a) Work of fracture

	1 mm vs 2 mm	2 mm vs 3 mm	1 mm vs 3 mm
T-test P	0.296	0.382	0.092
Result	n.s.	n.s.	Significant

(b) Jaggedness

	1 mm vs 2 mm	2 mm vs 3 mm	1 mm vs 3 mm
T-test P	0.021	0.661	0.108
Result	Significant	n.s.	Significant

(c) Avg. slope

	1 mm vs 2 mm	2 mm vs 3 mm	1 mm vs 3 mm
T-test P	0.324	0.357	0.034
Result	n.s.	n.s.	Significant

Table 7 shows a consistent pattern emerges: the 1 mm and 3 mm cassava crisps differ significantly in all three parameters (p < 0.10 for work, jaggedness; p ~0.03 for slope). In contrast, the intermediate 2 mm chips do not significantly differ from either 1 mm or 3 mm at this confidence level (all p > 0.25 except jaggedness vs 1 mm, which approached significance at p = 0.021). This suggests a graded texture change – the largest contrast is between the extremes (very thin vs thick chips), whereas the medium thickness chips are in between and not distinctly separate by these measures. For jaggedness, interestingly, even 1 mm vs 2 mm showed a significant difference (p = 0.021), implying that the very thinnest chips produce substantially more fracture events than slightly thicker chips.

The dried *Sus* cake was not included in Table 7, as pairwise tests involving *Sus* were conducted separately. However, analysis revealed that *Sus* cake's parameters were significantly different from the 3 mm cassava chips ($p < 0.05$ for all three metrics) and also different from the 2 mm chips ($p < 0.20$ for work and slope). Notably, *Sus* cake vs 1 mm chip showed no significant difference in work or slope (both extremely low) but did show a difference in jaggedness (the *Sus* cake had even higher jaggedness, though p ~0.15). These statistical outcomes reinforce that the *Sus* cake is as crisp as – or crisper than – the crispiest cassava chips.

3. 3 Comparison with Sensory Perception

Informal sensory observations aligned with the mechanical findings with *Sus* cake ≈ 1 mm chip > 2 mm chip > 3 mm chip, from most to least crisp. The dried *Sus* cake was described as "shattering" easily with a loud crunch, even more so than the thinnest cassava chip. This matches the instrumental conclusion that the *Sus* cake exhibits the highest crispness level (it had the lowest work required and one of the highest jaggedness indices). The fact that *Sus* cake is extremely porous (being a meringue-like foam) likely contributes to its high crispness: its structure contains many air cells, so it collapses with minimal force. In contrast, the thick cassava chip (3 mm) felt hard and crunchy, requiring a strong bite – consistent with its much higher fracture force and energy. This study demonstrates a methodology for quantitatively evaluating crispness using a multi-specimen compression approach. The key innovation is testing multiple pieces simultaneously, which provided a collective texture measurement representative of each product type. This is particularly useful for irregularly shaped snacks like the cassava crisps, where single-piece tests may be unreliable. By averaging many micro-fracture events in one compression, the multi-specimen test reduced variability and produced smooth indicators (e.g., stress–strain curve area) that differentiated texture levels [16, 17]. . Therefore, the mechanical parameters indeed capture the sensory crispness attributes of the foods.

3. 4 Crispness indicators

Among the parameters examined, *work of fracture, average slope, and jaggedness* emerged as effective descriptors of crispness. These findings are in line with previous works that identified low fracture energy and stiffness as markers of crispness. Jaggedness (reflecting abruptness and number of fractures) is a novel index in this context and proved sensitive, especially distinguishing subtle differences (e.g., between 1 mm and 2 mm chips) [15]. This aligns with the understanding that a truly crispy food tends to shatter into pieces rapidly, producing a highly irregular force pattern. The significant differences in jaggedness can observed bolster its use as a complementary metric alongside more traditional measures like work and slope.

3. 5 Effect of structure on crispn

The results highlight how sample thickness and porosity affect crispness. Thinner cassava slices fry into chips with less solid content and more internal void space, making them easier to break – hence crisper. Thicker slices retain more structure and moisture, yielding a crunchier, less brittle texture. This is consistent with sound-based studies, where thinner chips emit higher pitch sounds (associated with crispness) and thicker one's lower pitch (crunchiness). The *Sus* cake, while much thicker than the chips in size, is composed of a foamed matrix (from egg white and sugar) that is extremely fragile. Its high porosity and brittleness gave it a very low fracture resistance, akin to a delicate crisp. In fact, by our mechanical criteria, the *Sus* cake was *crispier* than any cassava chip. This underscores that material composition and structure (cellular vs solid) can outweigh geometric thickness in determining crispness. Foods with a high void fraction (like meringues, puffed cereals, freeze-dried snacks) can be extraordinarily crispy because the solid framework is minimal [18]. On the other hand, dense products (nuts, thick-cut chips) require greater force to break and may be perceived as crunchy or hard rather than crisp.

3. 6 Multi-specimen vs single-specimen testing

A key motivation for our method was to improve representativeness for non-uniform foods. Traditional single-chip compression might randomly hit a weak point or a strong point, leading to inconsistent results. By compressing many chips together, we effectively sample a distribution of breaking points in one test. Our data had relatively low variance (e.g., %RSD ~5–15% in work and slope within each group), indicating good repeatability, which is promising for industrial texture QC applications. In the multi-piece test, after initial fractures, fragments accumulate and begin to compress against each other, causing a secondary rise in force (see Figure 7(a) before and 7(b) after ~30 mm displacement).

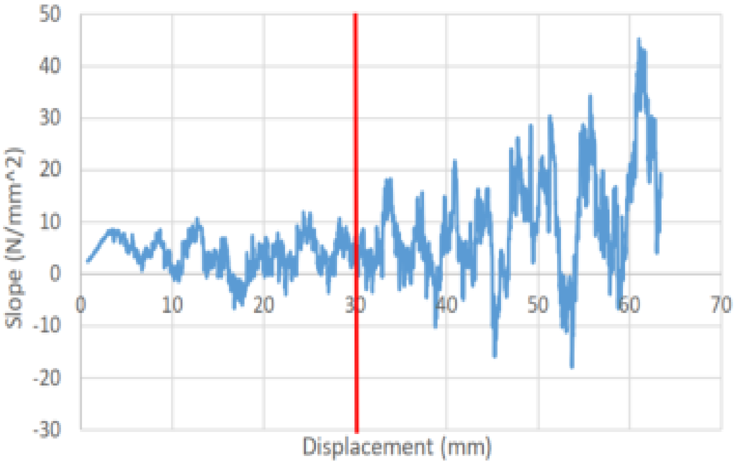


Figure 7 (a) Slope vs. Displacement Curve of Cassava Crisps with 1 mm Thickness

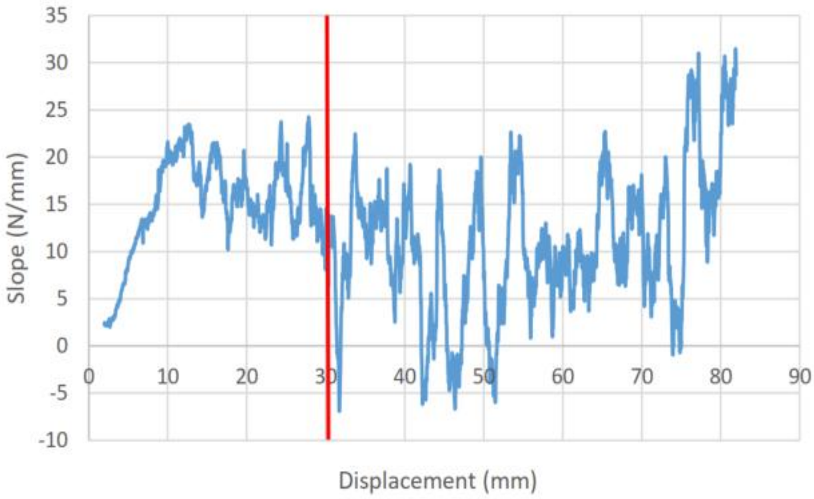
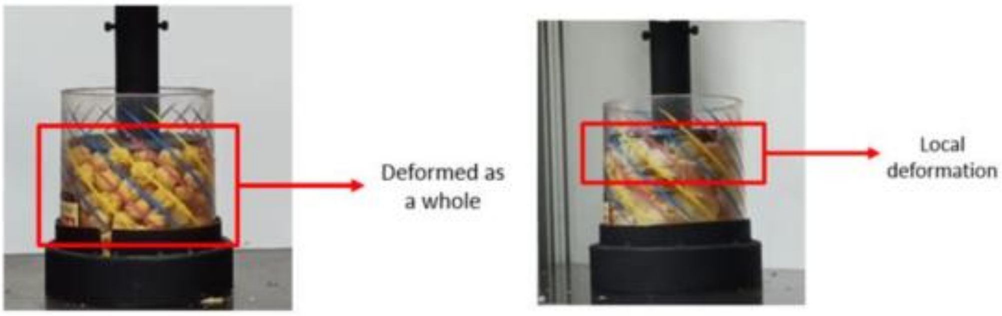


Figure 7 (b) Slope vs. Displacement Curve of *Sus* Cake

This densification could potentially mask differences if one sample type packs differently than another shown in Figure 8. Thin chips produced more fine fragments that filled gaps, possibly reaching a compact state sooner. We mitigated this by focusing our calculations (work, slope) up to the onset of densification, rather than to the very end of compression. Future refinements could include optimizing container dimensions to delay densification or normalizing for packed bulk density differences between samples. Nonetheless, in our results, the key differences were established well before the densification phase (e.g., most force peaks occurred prior to 50% strain).



(a) (b)

Figure 8 Densification Process (a) All Deformation; (b) Local Deformation

Jaggedness of the force curve is analogous to the number of sound events recorded – both reflect how many micro-fractures occur [7]. It is notable that the *Sus* cake, which had the highest force jaggedness, was also subjectively noted to produce the loudest, most continuous crunch sound. This suggests that the mechanical jaggedness index might be used as a proxy for acoustic crispness in situations where sound measurement is impractical. Arimi *et al.* (2010) developed an acoustic system for crispness and similarly found that combining sound and force data improves texture prediction [19]. The multi-specimen method inherently combines many simultaneous fractures, which may simulate the cumulative acoustic effect of biting a whole mouthful. Thus, it could be particularly useful for products typically consumed in handfuls (cereals, popcorn, etc.), where a single-particle test underestimates the sensory experience.

The multi-specimen compression test proved to be a practical and sensitive method for crispness evaluation. It captured the expected texture differences between products and corroborated sensory impressions. By providing quantifiable parameters, it offers food technologists a tool to benchmark crispness objectively and to compare new formulations, track texture changes during storage, or design products for specific consumer groups (e.g., an elderly-friendly chip that is easier to bite). The use of an existing UTM instrument with a simple container attachment means this method can be readily adopted in many laboratories without specialized acoustic equipment.

4. Conclusion

In this study, thin cassava chips showed significantly lower fracture energy and stiffness, and higher force irregularity, compared to thick chips, confirming greater crispness. The dried *Sus* cake, despite being a very different product, exhibited even greater crispness by these measures – a finding validated by sensory observation. These results demonstrate that our mechanical parameters correlate well with human perception and can distinguish even subtle textural differences. The multi-specimen method addresses the challenge of irregular sample shapes by effectively averaging their behavior, improving the reliability of crispness assessment for real-world snacks. It thus provides a pathway toward an objective crispness standard. For industry, this means the crispness of a product can be quantified and tailored: manufacturers can define a target range for, say, work of fracture or jaggedness index that corresponds to an ideal crisp eating experience, and adjust processing conditions (slice thickness, frying time, formulation) to achieve it. In conclusion, this research contributes a concise and effective analytical technique to food texture science. The significance of mechanical testing in demystifying a hitherto subjective attribute – crispness – and provided practical insights for both the academic understanding and industrial control of dry food texture.

5. Future Study

Expanding the sample scope (including more food types like crackers, extruded snacks) and refine the analysis. Incorporating simultaneous acoustic recording would be valuable to further validate the jaggedness index against sound event counts. Additionally, exploring different container sizes or sample masses could optimize the balance between capturing enough fractures and avoiding premature densification. Another extension is relating these mechanical crispness metrics to consumer acceptability – ultimately, confirming if the numeric values predict liking or quality ratings.

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CRediT Authorship Contribution Statement

Dara Ginanti: Conceptualization, Methodology, Formal analysis, Investigation, Writing – Original Draft. Kushendarsyah Saptaji: Methodology, Validation, Data Curation. Sri Hastuty: Resources, Supervision, Project administration. Farid Triawan: Conceptualization, Validation, Writing – Review & Editing, Supervision, Funding acquisition, Project administration.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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