

Physicochemical Properties and Shelf-Life Evaluation of Nutrient Fortified Dehydrated Tofu for Satiety

Fathul Naem Fathul Rahman¹, Saliza Asman^{2*}

¹ Department of Food Technology, Faculty of Applied Sciences and Technology
Universiti Tun Hussein Onn Malaysia (UTHM) 84600 Muar, Johor, Malaysia

^{2*} Department of Physics and Chemistry, Faculty of Applied Sciences and Technology
Universiti Tun Hussein Onn Malaysia (UTHM) 84600 Muar, Johor, Malaysia

*Corresponding Author: salizaa@uthm.edu.my

DOI: <https://doi.org/10.30880/ekst.2024.04.01.048>

Article Info

Received: 27 December 2023

Accepted: 14 June 2024

Available online: 27 July 2024

Keywords

Tofu, dehydrated, fortified, satiety

Abstract

Nutrient fortified dehydrated tofu is dehydrated fried tofu puffs that have vitamin supplements added in order to give a feeling of sustenance as well as provide nutrients. Satiating and nutritious foods come in useful in scenarios where hunger needs to be alleviated temporarily through the consumption of a compact and nutrient dense food. The physicochemical properties and shelf-life of NFDT was investigated along with assessing the satiation effect associated with its working principle. The physicochemical properties that were investigated were water-holding capacity where NFDT had higher WHC at 92.85 ± 1.14 %, colour analysis, and texture. Meanwhile, NFDT gave moisture content of 5.38 ± 0.19 . NFDT and CDT also had similar energy values. The fortification of tofu with vitamin supplement tablets also proved success because NFDT exhibited a vitamin B12 content of 400.29 mg per 100 g while CDT exhibited none. This proves that the tofu is fortified with vitamins. NFDT also was shown to be dehydrated sufficiently.

1. Introduction

This study delves into the development of nutrient fortified dehydrated tofu which intends to provide temporary satiation meanwhile providing nutrients as well. The significance of this study focuses on university students facing economic constraints, victims of flood who seek temporary relief from hunger while waiting for supplies to arrive and meal, ready-to-eat for soldiers and astronauts who need economical, nutritious and compact food options with an extensive shelf life. The research objectives aim to investigate the physicochemical properties, and shelf-life extension due to dehydration and the extent of satiation. The coagulant used to prepare nutrient fortified dehydrated tofu is calcium sulfate and fortified using a multi-vitamin supplement tablet. The satiation relief study is in accordance with the principle of the Satiety Cascade [1]. The Satiety Cascade outlines factors which has an influence on satiety which include cognitive, post-ingestive, sensory and post-absorptive signals. The texture of food impacts the oro-sensory exposure in addition to the stretch receptors in the stomach lining once activated signals nutrient intake to the brain [2].

Tofu is a protein source of soybean origin which is high in protein, vitamins, mineral, lipids and isoflavones [3][4]. Tofu consumption has also been known to be correlated with a reduced risk of cardiovascular disease [5]. The expansion properties of puffed tofu depend on factors like soy protein isolate formulations and mixing time [6]. Various frying methods impact the textural properties of tofu, with potential alternatives like vacuum frying and hot-air frying under exploration [7].

During the COVID-19 pandemic, university students faced challenges in maintaining a healthy lifestyle, resorting to light and frequent snacking in light of the lockdown restrictions, leading to a sedentary lifestyle. Many individuals relied on supplements in pill form to meet their estimated average requirements (EAR) [8]. Thus, an alternative to intake of nutrients, vitamins and minerals through food needs to be developed for the convenience of consumers to achieve their EAR. The mixing of supplements into food needs to have controlled thermal processing to ensure it does not degrade the supplement being fortified into it.

2. Materials and methods

The instruments used in the analyses were Moisture Analyzer (A&D Weighing | MX-50 Moisture Analyzer), food Dehydrator, High Speed Grinding Separating Machine, Texture Analyser (TA.XTplusC Stable Micro System Ltd., Godalming, United Kingdom), Colony Counter (HOVERLABS HV-37-CC, India), Centrifuge (5804 R, Eppendorf, Germany), Muffle Furnace (CDF 15-1C), Atomic Absorption Spectroscopy (240FS AA, Agilent Technologies, USA) and High-performance Liquid Chromatography (Thermo Electron, USA). The soybean used to make soybean milk was from the local supermarket bought in 1 kg packets. Meanwhile, the commercial *tofu pok* used as a reference or control was also found at the grocery store.

2.1 Preparation of dehydrated tofu

Raw soybeans of 1 kg were soaked for 8 hours at 25°C water overnight. The soybeans were drained, cleaned and weighed. The soybeans were put into the High-Speed Grinding Separating Machine with water that is double the weight of the soybeans. The soybean milk obtained was heated to 75°C for 5 minutes. Then, it was heated again up to 95°C for 5 minutes [9]. After that, the soybean was left to cool down to 80°C before stirring in 20g of gypsum powder as well as 3 crushed multi-vitamin supplement tablets which fortifies the tofu with vitamins and minerals. The soybean milk was left to coagulate for 20 minutes. The soybean whey liquid was pressed out from the curd in a tofu presser lined with muslin cloth. The block of tofu made was kept in the freezer overnight and thawed and dried with the paper towel before frying. Hot oil of temperature 170°C was used to fry 4 cm x 4 cm x 4 cm cubes of tofu for 3 minutes. The excess oil from the fried tofu was removed using a paper towel. The fried tofu was then placed in a Food Dehydrator at 70°C for 15 hours. A commercial dehydrated tofu (CDT) was compared as a reference.

2.2 Physicochemical properties

Physicochemical properties for this study of dehydrated tofu comprise of the analysis of water-holding capacity, colour, and texture analysis.

2.2.1 Water holding capacity (WHC)

WHC determination was conducted by cutting 5 g of the sample into 5 mm cubes and placed into a centrifuge (5804 R, Eppendorf, Germany) in a 50 ml centrifuge tube at 4000 rpm for 40 mins at 25°C. After that, the removal of the surface water of the sample was done by patting with paper towel. The WHC was calculated based on the Equation 1 stated below:

$$\text{WHC (\%)} = \frac{(A - B)}{A} \times 100 \quad (1)$$

A stand for the initial weight after rehydrating while B is the water lost after centrifugation

2.2.2 Colour analysis

A mobile smartphone application (Color Name AR) was used to measure the CIE L*, a* and b* values. Positive b* value indicates yellowness while negative value indicates blueness. Positive a* value shows redness while its negative values show greenness. L* value show the luminance of its brightness. The smartphone camera was ensured to be consistently 8 cm away from the sample while taking each reading of the inside and the crust [10].

2.2.3 Texture analysis

Texture profile analysis (TPA) was done to analyse the texture of dehydrated tofu. Texture Analyser (TA.XTplusC Stable Micro System Ltd., Godalming, United Kingdom) was used as it is found in the Food Instrumentation Laboratory in UTHM Pagoh. The settings of 1.00 mm/sec pre-test speed and post-test speed, 10.00mm/sec post-test speed, force of 100.0 g, distance of 40.000 mm, strain of 50.0%, 200 points per second, 20.0 g trigger force with a HDP/BSG; Blade Set with Guillotine probe was used to measure hardness [11].

2.3 Proximate analysis

Proximate analysis for this study of dehydrated tofu comprises of the analysis of moisture content, protein, fibre, energy value, sodium, fat, total carbohydrate and vitamin B12.

2.3.1 Moisture content analysis

Around 2 g of sample each, was cut to analyse in the moisture analyser (A&D Weighing | MX-50 Moisture Analyzer). A setting of 200°C in standard mode was used to assess the moisture content percentage in each sample [12].

2.3.2 Energy value

The energy value of the sample was determined using a Science First® Economy Calorimeter. The weights of the cork and needle were measured and recorded to adjust for the sample's weight when attached. Food samples, approximately 0.3 g each, were cut and prepared. The combined weight of the cork, needle, and the attached food sample was measured. Using a measuring cylinder, 50 ml of water was added to the flask, and the initial water temperature was recorded. The flask was then inserted into the calorimeter lid. Igniting the food sample, the maximum temperature reached by the water in the flask was noted.

2.3.3 Protein analysis

Protein analysis was conducted according to the established Kjeldahl method (MS 807:1983). The dehydrated tofu sample was weighed. The digestion process was done by mixing concentrated H₂SO₄ with the sample in the digestion flask and heat was applied. Then, the mixture was neutralized with NaOH. The product was then distilled using steam distillation. It was then collected in a flask containing a recorded volume of boric acid. The mixture was titrated with 0.1 mol HCl with phenolphthalein.

2.3.4 Fibre content analysis

The fibre content analysis was found through AOAC 985.29 [13]. The sample was dried and gelatinized using α -amylase at temperature 96°C of pH 6.0 for 30 min. Protease at 60°C of pH 7.5 for 30 min was used to digest protein while amyloglucosidase at 60°C of pH 4.5 for 30 min was used to digest starch, separately in incubation. In order to filter and wash the undigested residual, 78% ethyl alcohol, 95% ethyl alcohol and acetone were used for alcohol precipitation. The sample weight was subtracted by the resultant protein and ash to obtain total dietary fibre.

2.3.5 Sodium content analysis

The sodium content in the dehydrated tofu was analysed using atomic absorption spectrometry based on AOAC 975.03. The samples were placed in a muffle furnace (CDF 15-1C) at 600°C for 8 hours or more until the weight was constant. The remaining ash samples were digested with HCl-HNO₃ prepared in a 3:1 ratio. A Whatmann 44 filter paper was used to filter the solution formed into a 100 ml volumetric flask. Deionized water was added to the solution until the graduation mark. Five diluted samples were formed using the solution made. CsCl₂ is added to the solutions. The wavelength of AAS (240FS AA) sodium analysis utilizes wavelength 589.0 nm, slit 0.2 nm and air-acetylene [14]. The absorbance or intensity of the blanks, series of standards and samples was obtained and recorded. The concentration of sodium mineral was deduced.

2.3.6 Fat content analysis

The fat content of dehydrated tofu was determined using established AOAC 963.15 method of Soxhlet extraction [15]. 2 g of dehydrated tofu was wrapped in a porous filter paper and placed in a Soxhlet reflux filter. An oil extraction flask was weighed and filled with 200 ml petroleum ether. The condenser was connected to the reflux flask. Boiling of solvent was done using an electrothermal heater. The condensate in the reflux flask submerged the sample. The cycle will continue for 4 hours. The oil obtained was dried in an oven at 60°C for 30 min and stored in desiccator to cool before weighing.

2.3.7 Ash content analysis

The method of measuring ash content was according to AOAC 945.46. 2 g of sample was placed into weighed crucible. The samples were first charred on a hot plate before being put into a muffle furnace at 550°C for 6 hours. After that, the crucible was placed in a desiccator to cool before weighing. The ash content was calculated according to equation 2 [16].

$$\text{Total Ash (\%)} = \frac{(W_1 - W_2) \times 100}{S_w}, \quad (2)$$

W1 = weight of crucible and ash after incineration, W2 = weight of empty crucible,
SW = initial weight of the sample

2.3.8 Total carbohydrate analysis

Total carbohydrate was obtained by proximate analysis after obtaining other components such as moisture, fibre, fat, ash and protein content. The remainder after subtracting from 100% composition is the total carbohydrate.

2.3.9 Vitamin analysis

The bioavailability of vitamins that remain after the frying process was identified using high-performance liquid chromatography (HPLC). The existence of a small amount of vitamins proves that the dehydrated tofu is fortified with vitamins although only a small amount. The dehydrated tofu sample was homogenized by grinding. 3 g of sample was transferred into a 100 ml flask. 20 ml Tris (2-carboxyethyl)-phosphine hydrochloride acid solution was used to dissolve and acidify the sample. The solution was made up to the graduation mark of the 100 ml volumetric flask with 1% trichloroacetic acid (TCA) and tipped to ensure homogenization. A 0.45 µm membrane filter was used to filter the solution to be run in HPLC. The HPLC chromatogram obtained for the vitamin result analysis was interpreted to obtain the concentration of vitamin B12 based on the retention time

2.4 Shelf-life estimation analysis

The dehydrated tofu sample of weight 25 g was mixed with 225 ml of 0.1% peptone. Nutrient agar was prepared by dissolving 7 g of nutrient agar powder with 250 ml of distilled water. The agar solution and mixture of sample and peptone water were autoclaved for 15 mins at 121°C. The plates were prepared by labelling three Petri dishes for each sample and pouring agar solution. 100 µl of the sample was pipetted onto each agar plate. The plates were taken out of the incubator set at 37°C to observe the colony forming units (CFU) by using the colony counter daily. The petri dishes will remain in an incubator at 37°C when not being observed. [17]

2.5 Satiety analysis

An experiment designed based on the Satiety Cascade was made to assess the extent that dehydrated tofu can have on satiety and hunger suppression [18]. The experimental design is based on the sensory analysis technique of descriptive profiling method called quantitative descriptive analysis. The trained panellist developed a lexicon for describing satiety and hunger through discussion at a round table to discuss the extent and the threshold for assessing hunger. The 13 trained panellists were chosen based on their body weight class and gender as these are factors on satiety. The panellists were asked to fast after their dinner the previous night, before being served dehydrated tofu samples at around 7:00 A.M. the following morning. The time taken for the panellists to start feeling signs of hunger after ingesting the dehydrated tofu sample was recorded.

2.6 Statistical analysis

The results obtained from the analysis done were processed through Minitab to generate One-way ANOVA. Means along with the standard deviations of each result were obtained for comparison between samples as well as comparing between triplicates to assess accuracy.

3. Results and Discussion

3.1 Preparation of dehydrated tofu

The sample preparation involved extruding soybeans, creating raw firm tofu through a process of frying and dehydrating. The necessity of incorporating multivitamin supplement tablets into the tofu before coagulation led to the choice of preparing tofu from raw soybeans. The two-step heating process aimed at denaturing β-conglycinin (65°C-75°C) and glycinin (85°C-95°C) proteins, ensuring a thorough, orderly, and dense protein network in tofu curds. A five-minute heating at 75°C allowed complete dissociation of β-conglycinin, while a subsequent heating to 95°C resulted in glycinin dissociation and self-aggregation, creating a firmer tofu [9]. Freezing the pressed tofu overnight before frying induced ice crystal formation in the macro-complex, contributing to porous tofu puffs upon melting during frying. This porosity facilitates efficient water uptake during dehydration [4].

3.2 Physicochemical properties

3.2.1 Water holding capacity (WHC)

Water Holding Capacity (WHC) serves as a crucial measure to assess the water absorption capability within the matrix of tofu, reflecting its rehydration potential. This property signifies the capacity of the tofu sample to retain water within its structure, beyond surface absorption.

Table 4.1 illustrates that NFDT exhibits higher WHC compared to commercial tofu. NFDT's superior water-holding ability is attributed to the use of gypsum powder as a coagulant during its preparation, forming organized cross-links as proteins denature. This thorough coagulation leads to increased syneresis, enhancing [19]. Syneresis involves the shrinkage of the gel or tofu and expulsion of water to form whey protein and curds. A higher syneresis indicates a more complete coagulation, leaving a clearer whey protein liquid.

In the rehydration process, the dehydrated tofu sample was immersed in water for 20 seconds, with surface-level water removed by dabbing with a paper towel. Discrepancies among samples may arise due to variations in water uptake, influenced by rehydration duration, water temperature, and the inherent rehydration capacity of tofu [20].

Table 4.1 Water holding capacity of nutrient fortified dehydrated tofu and commercial dehydrated tofu

Sample	WHC, %
NFDT	92.85 ± 1.14 ^a
Commercial	73.57 ± 2.48 ^b

*The data is presented as mean of triplicate determinations ± SD. Mean that do not share a letter are significantly different (p<0.05)

3.2.2 Colour analysis

The colour analysis aimed to evaluate both the surface colour of the white interior and the crust of the tofu. The inside L*, a* and b* values were of no significance, the p value is more than 0.05. However, for crust value, all showed significance. Conversely, a significant difference (p<0.05) is found in the L* value of the crust, indicating that the NFDT crust is darker than commercial tofu. A reduced frying time would achieve a lighter colour

The standard deviations in Table 4.2 indicate reasonable result consistency. The use of the Color Name AR smartphone app emerges as a cost-effective alternative to high-end colorimeter equipment [21]. While caution and comparison with standard instruments are necessary, smartphone colorimeter apps can be considered as substitutes for the traditional colorimeter.

Table 4.2 Colorimeter reading of the inside and crust of NFDT and commercial dehydrated tofu

	Inside			Crust		
	L*	a*	b*	L*	a*	b*
NFDT	76.88 ± 4.06 ^a	1.89 ± 1.99 ^a	49.18 ± 8.52 ^a	44.21 ± 10.66 ^a	15.00 ± 4.18 ^a	42.17 ± 6.04 ^a
Commercial	75.67 ± 2.76 ^a	0.25 ± 0.34 ^a	49.26 ± 1.04 ^a	66.44 ± 8.43 ^b	7.98 ± 2.30 ^b	55.30 ± 8.90 ^b

*The data is presented as means of triplicate determinations ± SD. Means that do not share a letter are significantly different (p<0.05)

3.2.3 Texture analysis

Hardness, a measure of mechanical resistance, is a crucial attribute for brittle, dehydrated tofu samples. Texture analysis, influenced by mastication characteristics, revealed that the hardness of tofu did not impact the difficulty faced during chewing. Table 4.3 shows that commercial dehydrated tofu had the lowest hardness, attributed to its porosity. NFDT demonstrated higher hardness. Undehydrated samples, with firm tofu showing higher hardness than nutrient-fortified tofu. ANOVA indicated significance (p<0.05) in hardness while only commercial wet sample showed significant difference from the rest.

Table 4.3 *Texture Profile Analysis measuring hardness*

Sample	Hardness, Force, g
Nutrient-fortified dehydrated tofu	2586.36 ± 362.275 ^a
Commercial dehydrated tofu	2397.32 ± 254.842 ^a
Nutrient fortified tofu (Wet)	2779.14 ± 228.366 ^a
Commercial tofu (Wet)	4679.86 ± 328.781 ^b

*The data is presented from the mean of triplicate determination ± SD. Means that do not share a letter are significantly different (p<0.05)

3.3 Proximate analysis

3.3.1 Moisture content analysis

The moisture content of Nutrient Fortified Dehydrated Tofu (NFDT) was significantly reduced to 5.38 ± 0.19% compared to its wet counterpart at 64.07 ± 1.41%, indicating thorough dehydration in a food dehydrator. The nutrient-fortified sample had higher moisture content than commercial wet sample due to its denser composition compared to the porous commercial tofu.

Table 4.4 *Moisture content of dry and wet tofu samples*

Sample	Moisture content, %
NFDT	5.38 ± 0.19 ^a
CDT	13.60 ± 0.02 ^b
NFT (Wet)	64.07 ± 1.41 ^c
Commercial (Wet)	53.88 ± 2.98 ^d

*The data is presented from the mean of triplicate determination ± SD. Means that do not share a letter are significantly different (p<0.05)

3.3.2 Energy value

The energy value of NFDT and CDT showed no significance due to large standard deviation and p value more than 0.05. The nutritional composition values (22670 J/g for NFDT and 25827 J/g for commercial) were higher due to energy loss to the surroundings. The limitations of the experimental instrument, an economy calorimeter, assumed complete transfer of heat to water and did not account for heat released to the surroundings.

Challenges in the experimental setup included the need for burning small amounts of tofu due to ignition difficulties with larger samples and the brittleness of dehydrated tofu hindering accurate weighing with the needle attachment. An improvement suggestion was a more precise instrument like a bomb calorimeter, which operates under constant volume and is less influenced by surrounding temperature and heat loss [22].

Table 4.5 *Energy value of tofu sample*

Sample	Specific heat, J/g
NFDT	5222.94 ± 309.20 ^a
CDT	5578.95 ± 1654.70 ^a

*The data is presented from the mean of triplicate determination ± SD. Means that do not share a letter are significantly different (p<0.05)

3.3.3 Proximate composition analysis

The nutritional composition analysis highlighted significant differences between Nutrient Fortified Dehydrated Tofu (NFDT) and Commercial Dehydrated Tofu (CDT). NFDT exhibited a sodium content of 6.95 mg per 100g, surpassing CDT's 2.87 mg. The fat content in NFDT was notably high at 49.51 g per 100g.

Ash content in NFDT was measured at 5.40 g per 100g, higher than CDT's 2.87 g. NFDT displayed a carbohydrate content of 3.35 g per 100g, while CDT showed none. The calculation method, subtracting the sum of moisture, ash, fat, fibre, and protein from 100%, may have led to overestimation reported as 5.33% carbohydrate content for a similar coagulation method [23].

Vitamin B12 in NFDT was found to be 400.29 mg per 100 g. Meanwhile, CDT had no vitamin B12. This is in line with the fact that NFDT was fortified with vitamins and the thermolabile vitamin B12 survived the denaturation. The protein content analysis revealed that NFDT contains 20.71 g of protein per 100 grams, while CDT had higher at 33.62 g per 100 grams. This difference is likely due to the soybean cultivar used, with commercial tofu potentially utilizing higher-quality soybeans. In terms of fibre content analysis, both NFDT and CDT showed no detectable fibre, possibly due to the removal of soybean hulls during processing.

<i>NUTRITION FACTS</i>		
Net Weight	:	100 g
Serving Size	:	100 g
Serving per package	:	1
<i>Amount</i>	<i>Per 100 g</i>	<i>Per serving</i>
Energy	541.83 kcal	541.83 kcal
	2264.85 kJ	2264.85 kJ
Protein	20.71 g	20.71 g
Carbohydrate	3.35 g	3.35 g
Dietary Fibre	0.00 g	0.00 g
Total Fat	49.51 g	49.51 g
Moisture	21.03 g	21.03 g
Ash	5.40 g	5.40 g
Sodium	6.95 mg	6.95 mg
Vitamin B12	400.29 mg	400.29 mg
Calories per gram :		
Fat	9	Carbohydrate 4 Protein 4 TDF 2

Fig. 4.1 NFDT nutritional composition

<i>NUTRITION FACTS</i>		
Net Weight	:	100 g
Serving Size	:	100 g
Serving per package	:	1
<i>Amount</i>	<i>Per 100 g</i>	<i>Per serving</i>
Energy	617.27 kcal	617.27 kcal
	2580.19 kJ	2580.19 kJ
Protein	33.62 g	33.62 g
Carbohydrate	0.00 g	0.00 g
Dietary Fibre	0.00 g	0.00 g
Total Fat	62.63 g	62.63 g
Moisture	21.10 g	21.10 g
Ash	2.87 g	2.87 g
Sodium	26.90 mg	26.90 mg
Vitamin B12	0.00 mg	0.00 mg
Calories per gram :		
Fat	9	Carbohydrate 4 Protein 4 TDF 2

Fig. 4.2 CDT nutritional composition

3.4 Shelf-life estimation analysis

The shelf-life analysis revealed that NFDT, with reduced moisture content, exhibited a faster microbial growth rate compared to CDT. The dehydration process aims to extend the shelf life of NFDT, allowing it to be stored at room temperature (25°C) for an extended period, potentially weeks. However, some plates showed no microbial growth due to improper handling of microbiological equipment, such as insufficient cooling of the cell spreader

and inadequate homogenization of the sample in the stomacher. These factors may have contributed to accelerated colony growth on the media plates. Serial dilution process should have been done to calculate the log/g. Then, it can be compared to total bacterial count of fresh tofu at day 4 which was 9.25 ± 0.01 [23]. Intermediate moisture foods which have moisture content of 15%-40% are considered safe for consumption. [24]. NFDT which has moisture content of 5.38 ± 0.19 is lower than IMF foods.

Table 4.6 Total plate count analysis of tofu sample

	Mean of colony growth, CFU	Day						
		1	2	3	4	5	6	7
NFDT					20	21	22	23
Commercial					10	11	11	13

3.5 Satiety analysis

The data shown in Fig. 4.7 showed that the duration of hunger suppression varied greatly. The p value showed the data was not significant. The average weight of the 13 panellists were 67 kg with a standard deviation of 16.6 kg. There was a diverse range of weights ranging from 45 kg to 97 kg. The age demographic was kept similar, where panellists ranged from ages 21 to 24 who are all students who live similar lifestyles [1]. The duration of time that hunger is suppressed is suitable as a hunger suppressant while waiting for a complete meal. The longest a panellist went without eating after consuming NFDT was 7 hours and 15 minutes and weighed 76 kg. The sample size is too small to deduce a relationship between weight class and duration of hunger suppression. This is because although morphologically there is a difference between panellists, there are other factors which are underlying such as metabolic rate, lifestyle and secretion of hormones [2].

Besides this method, there should be a study of the rehydration ratio of NFDT to observe the extent of expansion in the volume of the tofu sample when rehydrated to simulate the absorption of water in the stomach that will swell up the tofu. The swelling in volume aims to fill the stomach until the bolus touches the stretch receptors in the wall of the stomach which will trigger a cascade of neurotransmitter signals to the brain signalling satiety or fullness. According to the Satiety Cascade, the nervous system influences cell signalling of hunger in various ways. The factors include the size of the food, texture and even the oro-sensory system [4]. Hunger is also expressed in a vague sense from individual to individual but is known to be factored by body weight, gender and energy expenditure.

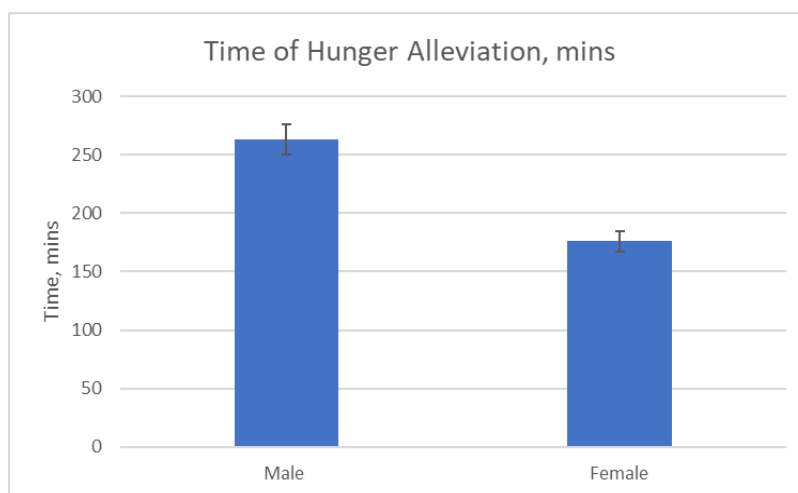


Fig. 4.7 Bar graph of hunger alleviation in minutes between male and female

4. Conclusion

In conclusion, NFDT was made using soybean milk coagulated with gypsum powder. The temperature of cooking as well as the concentration of coagulant is important for the texture and water-holding capacity of the tofu. The colour of the tofu formed is dependent on the frying time. The hardness of the tofu measures the mechanical resistance of the tofu when impaled with a metal guillotine probe. The moisture content of NFDT is lower than CDT. Dehydrating the tofu at 70°C for 15 hours dehydrated the tofu thoroughly. Meanwhile, the shelf life could

not be determined because of limitations in results obtained. The protein content of CDT is higher than NFDT which could be due to the coagulation technique and cultivar of soybean used. The fortification of NFDT was successful despite application of heat towards thermolabile vitamin B12.

Acknowledgement

This research was made possible by the Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia. I would like to thank all the laboratory and assistant engineers for making this learning experience smooth and fulfilling.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

*The authors confirm contribution to the paper as follows: **study conception and design:** Fathul Naeem Fathul Rahman, Saliza Asman **data collection:** Fathul Naeem Fathul Rahman; **analysis and interpretation of results:** Fathul Naeem Fathul Rahman, Saliza Asman; **draft manuscript preparation:** Fathul Naeem Fathul Rahman, Saliza Asman. All authors reviewed the results and approved the final version of the manuscript.*

References

- [1] Ali, F., Tian, K., & Wang, Z. X. (2021). Modern techniques efficacy on tofu processing: A review. In Trends in Food Science and Technology (Vol. 116, pp. 766–785). Elsevier Ltd. <https://doi.org/10.1016/j.tifs.2021.07.023>
- [2] Basolo, A., Parrington, S., Ando, T., Hollstein, T., Piaggi, P., & Krakoff, J. (2020). Procedures for Measuring Excreted and Ingested Calories to Assess Nutrient Absorption Using Bomb Calorimetry. *Obesity*, 28(12), 2315–2322.
- [3] Bertrand, L., Shaw, K. A., Ko, J., Deprez, D., Chilibeck, P. D., & Zello, G. A. (2021). The impact of the coronavirus disease 2019 (Covid-19) pandemic on university students' dietary intake, physical activity, and sedentary behaviour. *Applied Physiology, Nutrition and Metabolism*, 46(3), 265–272.
- [4] Chambers, L. (2016). Food texture and the satiety cascade. *Nutrition Bulletin*, 41(3), 277–282.
- [5] Chavan, S. M., Verma, R. C., & Sharma, G. P. (2018). Textural and Sensory Characteristics of Hot Air-dried Tofu. In *Journal of Agricultural Engineering* (Vol. 55, Issue 3).
- [6] Dehghannya, J., & Ngadi, M. (2021). Recent advances in microstructure characterization of fried foods: Different frying techniques and process modeling. In Trends in Food Science and Technology (Vol. 116, pp. 786–801). Elsevier Ltd.
- [7] Ezeama, C. F., & Dobson, G. N. (2019). Effect of coagulants on the physicochemical properties of fresh tofu. *African Journal of Food Science*, 13(12), 287–296.
- [8] Forde, C. G. (2018). Measuring satiation and satiety. In *Methods in Consumer Research, Volume 2: Alternative Approaches and Special Applications* (pp. 151–182). Elsevier.
- [9] Gibbons, C., & Blundell, J. E. (2019). Quantifying appetite and satiety. In *Translational Research Methods in Diabetes, Obesity, and Nonalcoholic Fatty Liver Disease: A Focus on Early Phase Clinical Drug Development* (pp. 121–140). Springer International Publishing.
- [10] Im, J., & Park, K. (2021). Association between soy food and dietary soy isoflavone intake and the risk of cardiovascular disease in women: A prospective cohort study in Korea. *Nutrients*, 13(5).
- [11] Ingrid, M., & Hananjaya, N. (2020). The Effect of Salt-GDL Coagulant and Temperature on Tofu Quality. *IOP Conference Series: Materials Science and Engineering*, 742(1).
- [12] Kanamori, J. (2019). Study of complex systems III-macro-scopic approach on the thermal expansion of deep-fried tofu.
- [13] Lu, W., Zhang, Y., Zhang, C., Chen, D., & Xiao, C. (2023). Influence of calcium sulfate incorporated with gluconolactone coagulant on the quality of whole soybean flour tofu. *Food Chemistry*: X, 17.
- [14] Malavi, D., Mbogo, D., Moyo, M., Mwaura, L., Low, J., & Muzhingi, T. (2022). Effect of Orange-Fleshed Sweet Potato Purée and Wheat Flour Blends on β -Carotene, Selected Physicochemical and Microbiological Properties of Bread. *Foods*, 11(7).
- [15] Perez-Palacios, T., Salas, A., Muñoz, A., Ocaña, E. R., & Antequera, T. (2022). Sodium chloride determination in meat products: Comparison of the official titration-based method with atomic absorption spectrometry. *Journal of Food Composition and Analysis*, 108.

- [16] Rahaman, A., Zeng, X. A., Kumari, A., Rafiq, M., Siddeeg, A., Manzoor, M. F., Baloch, Z., & Ahmed, Z. (2019). Influence of ultrasound-assisted osmotic dehydration on texture, bioactive compounds and metabolites analysis of plum. *Ultrasonics Sonochemistry*, 58.
- [17] Riyad, Y. M., Naeem, M. M. M., Helmy, M. M., & Sorour, M. A. (2020). Preparation Of Edible Coating Incorporated With Lemon Balm (*Melissa Officinalis L.*) For Extending Shelf Life Of Tofu.
- [18] Silsin, M., Khongdan, J., Darma Paramita, V., & Panyoyai, N. (2021). Effect of partial replacement of soybean with chickpea to the nutritional and textural properties of tofu. In *Indonesian Food Science and Technology Journal IFSTJ* (Vol. 4).
- [19] Sirisathitkul, Y., & Kaewareelap, S. (2021). Color Analysis of Batik Fabric by Facile Smartphone Colorimetry. *International Journal on Advanced Science, Engineering and Information Technology*, 11(1), 84–91.
- [20] Tripathi, M. K., & Mangaraj, S. (2013). Effect of Coagulants on Nutrient and Antinutrient Parameters of Soy Tofu. In *Trends in Biosciences* (Vol. 6, Issue 2).
- [21] Yang, X., Wang, Y., Hao, M., & Li, L. (2020). Synergistic effect of the lactic acid bacteria and salt coagulant in improvement of quality characteristics and storage stability of tofu. *Journal of Oleo Science*, 69(11), 1455–1465.
- [22] Zhang, Q., Wang, C., Li, B., Li, L., Lin, D., Chen, H., Liu, Y., Li, S., Qin, W., Liu, J., Liu, W., & Yang, W. (2018). Research progress in tofu processing: From raw materials to processing conditions. *Critical Reviews in Food Science and Nutrition*, 58(9), 1448–1467.
- [23] Al-Maqtari, Q. A., Alkawry, T. A. A., Odjo, K., Al-Gheethi, A. A. S., Ghamry, M., Mahdi, A. A., Al-Ansi, W., & Yao, W. (2023). Improving the shelf life of tofu using chitosan/gelatin-based films incorporated with *Pulicaria jaubertii* extract microcapsules. *Progress in Organic Coatings*, 183. <https://doi.org/10.1016/j.porgcoat.2023.107722>
- [24] Srijeeta Saha. (2020). IMF: To Enhance the Shelf-Life of Food. *International Journal for Modern Trends in Science and Technology*, 6(10), 103–108. <https://doi.org/10.46501/ijmtst061018>