

Effect of Coagulants on Yield and Quality Characteristics of *Hibiscus cannabinus* Seed Tofu

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Abstract

Kenaf (*Hibiscus cannabinus*) is a yearly herbaceous plant of economic significance. Devotion on the kenaf plant has focused on the fiber-based industries. Also, the leaves have received little applications in herbal medicine, whereas the seed has been underutilised despite its high nutritional profile particularly as raw material for the food industries. This study endeavour to value-add kenaf seed as raw material for tofu production. Accordingly, the effects of coagulants on the yield, proximate composition, texture profile analysis (TPA) and sensory characteristics of kenaf seed tofu were studied. Four different food grade coagulants which includes glucono-delta-lactone (C₆H₁₀O₆), aluminium potassium salt (KAl(SO₄)₂.12H₂O), citric acid (C₆H₈O₇) and calcium sulphate (CaSO₄) were used for the kenaf seed tofu production. Soybean tofu coagulated with CaSO₄ was used as control. The results indicated that the control tofu had significantly higher yield of 344.97 g/L, followed by kenaf seed tofu coagulated with C₆H₁₀O₆ of 220.13 g/L yield and the kenaf seed tofu coagulated with CaSO₄ had the least yield of 106.50 g/L. Also, the control tofu had significantly higher TPA and sensory scores than the kenaf seed tofu. Likewise, the coagulant types significantly affected the yield, TPA, and sensory score of the kenaf seed tofu. In term of the proximate composition, the coagulant types had no significant effect on the crude lipid and moisture content of the

kenaf seed tofu. However, the crude protein, ash and carbohydrate by difference were significantly affected. This study recommends the use of $C_6H_{10}O_6$ and $KAl(SO_4)_2 \cdot 12H_2O$ as coagulants to produce kenaf seed tofu.

Keywords: Kenaf seed, tofu, coagulant, quality characteristics, sensory

INTRODUCTION

Tofu is a commonly consumed vegetable protein-based food product in Africa and Asian countries and gradually becomes popular in Western countries because of its nutritional content and texture profile analysis [1]. The traditional processes of tofu preparation involve; soaking of vegetable seed for 8-10 h at room temperature (28 ± 2 °C), grinding of the soaked seed with water and removal of residual fiber from the slurry [2]. The obtained extract will then be coagulated with coagulant after heating to 95 °C, and the whey will be separated from the curd by moulding in a box lined with muslin cloth [3–5]. Several processing conditions such as seed-to-water ratio, heat processing [6], type and concentration of coagulants [7–11], stirring speed and temperature of coagulation [6], and moulding time and pressure [12] have been reported to affect the quality of tofu. Many coagulants have been used in the preparation of tofu, each resulted in tofu with different texture profile analysis, with varied moisture content between 70 to 90% [8]. Calcium sulfate and glucono-delta-lactone (GDL) are commonly used coagulants in tofu production, both coagulants have been reported to formed fine and uniform texture tofu [8].

Kenaf (*Hibiscus cannabinus*) is an herbaceous plant of Mallow family with history of over 4000 BC, it is a notable horticultural plant of economic benefit [13]. The kenaf plant is well known as raw material for rope, agricultural packaging sacs, paper, automotive and constructions [13,14]. The kenaf plant consist of the seed, which has been reported as source of vital nutrients such as protein, essential amino acids, unsaturated fatty acids, antioxidant rich phytochemical compounds and dietary fiber [15–17]. Many countries focused on the plantation of kenaf plant due to the multipurpose uses and economic significant of the fiber [18]. With the recent development of kenaf plantation in many countries to meet up with the demand for fiber and forage companies, surplus of kenaf seed will be harvested and this need to be value-added most especially in the food sector because of the nutritional content of the seed. Soybean has been known as the most commonly used vegetable protein in tofu production, however, the potential of other vegetable seeds for tofu making have been reported, such as peanut (19), mungbean [20] and sesame seed [21]. Also, recent studies by one of the author on KB6 kenaf seed has demonstrated the potential of using kenaf seed as an ingredient for tofu production [22]. Previous studies on soybean tofu have reported the effect of soybean cultivar on the quality attributes of soybean tofu [23,24]. Thus, this current study is a follow-up of the study of Ibrahim et al. [22] to determine the suitability of producing tofu using Ifeken DI 400 kenaf seed variety and to determine the effect of coagulant types on the yield, proximate composition, texture profile analysis and sensory characteristics of the kenaf seed tofu.

MATERIALS AND METHODS

Materials

Kenaf seed variety Ifeken DI 400 locally cultivated in Nigeria was used in this study. The seed was thoroughly cleaned by removing unwanted materials such as stones, debris and broken seeds. The coagulants used were food grade procured from Sigma-Aldrich (St. Louis, US) include glucono-delta-lactone ($C_6H_{10}O_6$), calcium sulphate ($CaSO_4$), aluminium potassium salt ($KAl(SO_4)_2 \cdot 12H_2O$) and citric acid ($C_6H_8O_7$). All other chemicals used were of analytical grade.

Preparation of kenaf milk extract

The sorted kenaf seed was thoroughly washed under running water and the washed seed was soaked in tap water at 1:6 seed-to-water ratio at 28 °C for 10 h. The soaked seed was then ground with water (three times dry seed weight) using a Waring blender (PBB 212, China). The kenaf seed slurry was then filter using double-layer cheese cloth, which separate the kenaf milk extract from the residues. Similar procedure was followed for the extraction of soybean milk which served as the control.

Preparation of kenaf seed tofu

The kenaf seed milk extract (400 mL) obtained from 100 g of kenaf seed was heated in a stainless-steel pot to 95 °C with occasional stirring and maintained at the aforementioned temperature for 2 min. A suspension of coagulant was prepared by dissolving 2.0 g% of coagulant in 20 mL of distilled water. To the heated kenaf milk extract, a solution of the coagulant was immediately added and stirred thoroughly for 10 sec. The coagulated extract was allowed to stand at room temperature (28 ± 2 °C) until the temperature drops to 70 °C, after which it was poured into a plastic mould lined with muslin cloth and a force of 15 kg was applied for 10 min. The weight of the freshly prepared kenaf seed tofu was recorded after the curd had been cool, and it was cut into blocks and stored at 4 °C for further analysis. The control (soybean tofu) was prepared following the same method used for kenaf seed tofu and calcium sulphate was used as coagulant.

Proximate analysis of kenaf seed tofu

The proximate composition (moisture, ash, crude lipid, crude protein, crude fiber and carbohydrate by difference) of the kenaf seed tofu were determined on wet basis according to the standard method of the Association of Official Analytical Chemists [25].

Texture profile analysis of kenaf seed tofu

Instrumental texture profile analysis (TPA) of the tofu was analysed following the method of Zhang et al. [5] with slight modification. Stable Micro System texture analyser (TA-HD plus 5085, Germany) was used to quantify the hardness, springiness, cohesiveness and chewiness of the kenaf seed tofu and the control (soybean tofu). The tofu sample was cut into a block of 4.0 cm x 4.0 cm x 2.0 cm from the centre position and 70% strain was applied using P36R probe at 1.0 mm/s of pre-test, test and post-test speed.

Sensory evaluation of kenaf seed tofu

Sensory quality of freshly prepared kenaf seed tofu was determined using 26 untrained panelists who were familiar with soybean tofu quality characteristics. The tofu samples were cut into smaller cubic shape and assigned with a 3-digit random number and presented to the panelists to evaluate on the attributes of odour, colour, appearance, texture and overall acceptability using 9-point Hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely) following the method of Noh et al. [3] with slight modification.

Data analysis

All analyses were carried out in triplicates except for the human sensory score which was replicated twenty-six times. Minitab statistical software (Version 17; Pennsylvania, USA) was used for data analysis and results were presented as mean $\pm$ standard deviation. One-way analysis of variance (ANOVA) was used to separate differences among the means following Tukey's multiple comparison test at 95% confidence limit.

RESULTS AND DISCUSSION

Figure 1 presents the effects of coagulants on the yield and pH of kenaf seed tofu. The yield of the kenaf seed tofu were significantly lower than the soybean tofu (control). Similar lower yield of kenaf seed tofu had been reported in the earlier study [22], and this is an indication that cultivar variation of kenaf seeds have no significant effect on the yield of the tofu and both the KB6 and Ifeken DI 400 could be used for the production of kenaf seed tofu. Likewise, the type of coagulant used for the tofu coagulation significantly affected the yield of the tofu. The kenaf seed tofu made with glucono-delta-lactone ($C_6H_{10}O_6$) had significantly higher yield than the kenaf seed tofu produced with the other coagulants. The kenaf seed tofu made with calcium sulphate ($CaSO_4$) had the least yield. Coagulant types used for tofu production have been shown to have effects on tofu quality [26,27]. Similar variation in the yield of soybean tofu made from different coagulants had been reported by Obatolu [26].

The pH of the tofu significantly differs from the control, except for the kenaf seed tofu made with aluminium potassium salt ($\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$) which had similar pH with the control. Equally, the pH of the kenaf seed tofu varied based on the different coagulants. The tofu made with CaSO_4 had significantly higher pH, this corroborates with the significantly lower yield of the tofu. Although, pH had been observed as an important factor for tofu coagulation to occur but, its value had been reported to be immaterial toward increasing the tofu yield [2]. The pH of the kenaf seed tofu range from 4.80 to 5.77, these values were consistent with the pH range of soybean tofu as reported by other researchers [2,28].

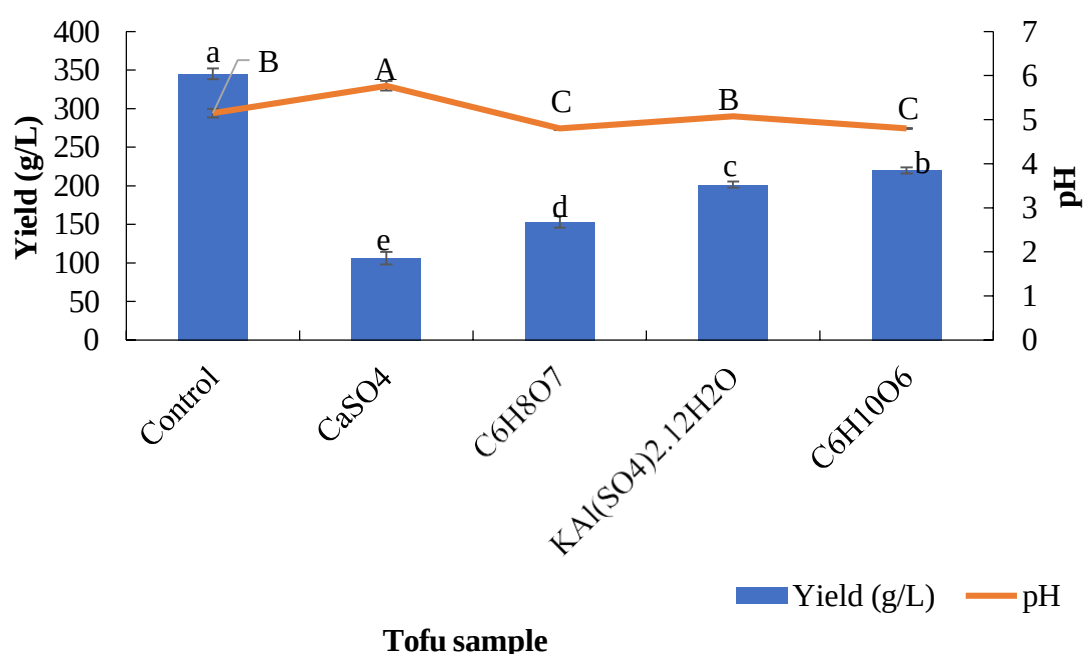


Figure 1. Effects of coagulants on the yield and pH of kenaf seed tofu.

Lower-case letter a-e indicate significant difference in the yield of the tofu. While the upper-case letter A-C indicate significant difference in the pH of the tofu at $\alpha = 0.05$

The proximate composition of kenaf seed tofu (Table 1) show that the coagulant types have no significant effect on the moisture and crude lipid contents of the kenaf seed tofu. However, the moisture and crude lipid contents of the control tofu were significantly higher and lower, respectively than the values found for the different coagulated kenaf seed tofu. The significantly higher moisture content of the control tofu and lower crude lipid might have accounted for the significantly higher yield of the tofu. As soybean tofu was known to have higher water holding capacity due to the

favourable protein-water interaction in the soybean tofu matrix [2,29]. Furthermore, lower crude lipid will have minimal interference on protein-protein, protein-water interaction than higher crude lipid content and will subsequently facilitate favourable coagulation process which will improve the bulk yield of the tofu. The significantly higher crude lipid content of the different coagulated kenaf seed tofu could be due to the initial higher crude lipid content (22.1 to 24.8 g%) of kenaf seed [30–32] in comparison to 18.2 to 20.0 g% in soybean [33,34].

The ash and carbohydrate contents of the control tofu were significantly lower than the different coagulated kenaf seed tofu. The tofu made with calcium sulphate and aluminium potassium salt had significantly higher ash content. On the other hand, the crude protein content of the control tofu was significantly higher than the kenaf seed tofu made from the different coagulants. These might be due to the higher crude protein content of soybean 37.4 to 40.0 g% [34,35] than 21.4 to 30.5 g% in kenaf seed [30,32]; which will subsequently reflect in the chemical composition of the final tofu product. The coagulant types affected the crude protein content of the kenaf seed tofu, the GDL-coagulated kenaf seed tofu had significantly higher crude protein than the tofu coagulated with the other coagulants. However, both citric acid and aluminium potassium salt coagulated tofu had similar crude protein content and the tofu made with calcium sulphate had the least crude protein content. The significantly higher crude protein content of GDL-coagulated tofu and significantly lower crude protein content of calcium sulphate-coagulated tofu might be due to the fact that acidic coagulants create a better coagulating microenvironment for protein interaction with other component of vegetable milk extract than salt coagulants [35]. Furthermore, the differences in the ionic strength of the coagulants will affect the coagulating capacity of the coagulants and subsequently affect the amount of the milk extract protein being coagulated which in turn will affect the crude protein content of the tofu product [35].

Table 1. Effects of coagulants on the proximate composition of kenaf seed tofu

	Moisture	Crude protein	Crude lipid	Ash	*Carbohydrate
	g%				
Control	82.11±0.76a	14.46±0.75a	1.46±0.34b	0.85±0.05d	1.12±0.11d
CaSO ₄	80.83±0.15b	6.76±0.55d	3.20±0.28a	2.00±0.55a	6.20±1.63b
C ₆ H ₈ O ₇	80.83±0.12b	7.70±0.49c	3.26±0.38a	1.62±0.22c	6.58±2.42a
KAl(SO ₄) ₂ ·12H ₂ O	80.91±0.11b	7.89±0.47c	3.44±0.65a	1.95±0.23a	5.80±1.47c
C ₆ H ₁₀ O ₆	80.51±0.28b	8.66±0.50b	3.29±0.38a	1.87±0.15b	5.67±1.20c

Values are mean ± standard deviation of triplicates. The values with the same letter down a column are not significantly different at $\alpha = 0.05$. a = carbohydrate by difference.

The TPA characteristics is an important quality attributes that affect consumer buying and acceptance of tofu product. Hardness, chewiness, springiness and cohesiveness are some textural parameters that determines the overall quality attributes of a tofu. Hardness is the force needed to compress a tofu sample at 70% strain. A tofu with a higher hardness value means harder and firmer. The hardness (1480.14 g) and chewiness (955.00) of the control tofu were significantly higher than the different coagulated kenaf seed tofu (Figure 2). Likewise, the coagulant types significantly affected the hardness and chewiness of the kenaf seed tofu. The GDL-coagulated tofu had significantly higher hardness and chewiness values of 556.61 g and 417.11, respectively. Followed by the tofu coagulated with aluminium potassium salt and citric acid, while tofu made with calcium sulphate had the least hardness and chewiness values of 177.52 g and 84.42, respectively. Earlier studies [10,26] had reported similar effects of coagulants on the textural characteristics of soybean tofu.

The higher the force required to deform the tofu, the higher the chewiness value will be, i.e more energy will be required to chew the tofu. These indicate direct relationship between the hardness and chewiness characteristics of the control and all the different coagulated kenaf seed tofu. The significantly lower hardness and chewiness obtained for the calcium sulphate-coagulated tofu signified that the tofu was softer than the other tofu coagulated with citric acid, glucono-delta-lactone and aluminium potassium salt.

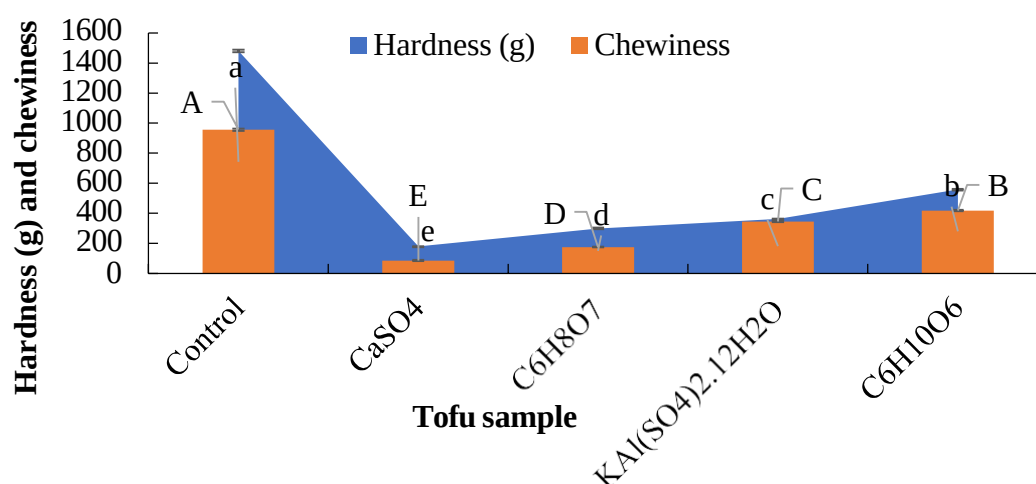


Figure 2. Effects of coagulants on the hardness and chewiness of kenaf seed tofu.

Lower-case letter a-e indicate significant difference in the hardness of the tofu.

While the upper-case letter A-E indicate significant difference in the chewiness of the tofu at $\alpha = 0.05$

The control tofu had significantly higher springiness (0.92 mm) and cohesiveness (0.71) than the different coagulated kenaf seed tofu (Figure 3). Furthermore, the coagulant types significantly affected the springiness and cohesiveness of the kenaf

seed tofu. The kenaf seed tofu coagulated with glucono-delta-lactone had significantly higher springiness (0.44 mm) and cohesiveness (0.55) than the other coagulated kenaf seed tofu except for the tofu coagulated with citric acid which had similar springiness with the above-mention tofu but of lower cohesiveness (0.35). On the other hand, the tofu coagulated with calcium sulphate had significantly lower springiness (0.27 mm) and cohesiveness (0.39).

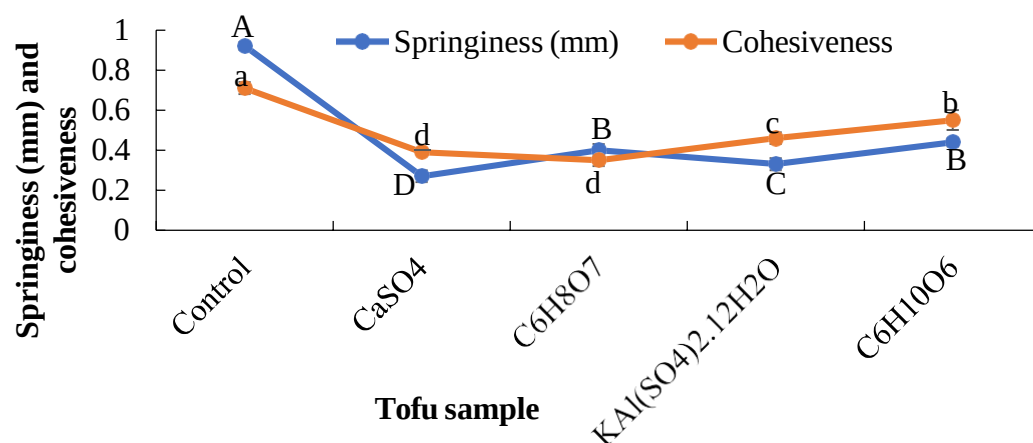


Figure 3. Effects of coagulants on the springiness and cohesiveness of kenaf seed tofu. Lower-case letter a-d indicate significant difference in the cohesiveness of the tofu. While the upper-case letter A-E indicate significant difference in the springiness of the tofu at $\alpha = 0.05$

The control tofu had significantly high sensory scores in term of colour, appearance, odour, texture and overall acceptability in comparison to the kenaf seed tofu (Figure 4). The coagulant types significantly affected the sensory characteristics of the kenaf seed tofu. The tofu made with glucono-delta-lactone and aluminium potassium salt had significantly higher scores for colour, texture and appearance. In addition, only GDL-coagulated kenaf seed tofu had significantly higher scores of above 5.0 for odour and overall acceptability than the other kenaf seed tofu coagulated with calcium sulphate, aluminium potassium salt and citric acid. Furthermore, the sensory quality for the kenaf seed tofu corroborate with the instrumental quality for hardness and chewiness. More importantly, the hardness and chewiness of the kenaf seed tofu coagulated with glucono-delta-lactone reflected on the sensory characteristics of the tofu. On the other hand, the significantly lower sensory score of calcium sulphate coagulated tofu agrees with its lower instrumental hardness and chewiness values.

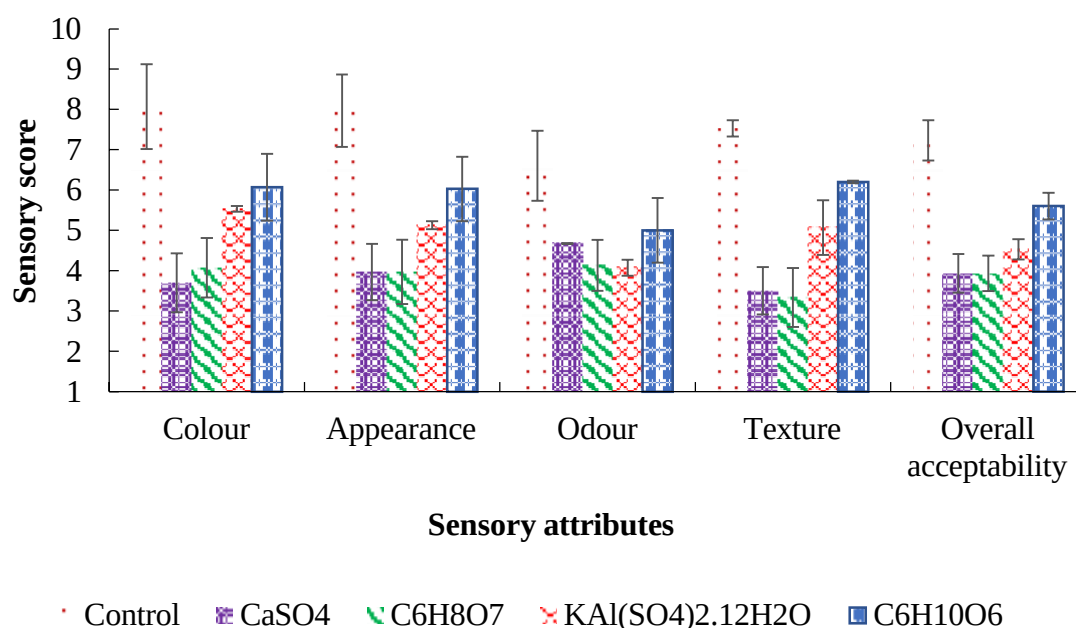


Figure 4. Effects of coagulants on the sensory attributes of kenaf seed tofu.

Results are mean $\pm$ SD (vertical error bars) of 26 replicates

CONCLUSION

This study indicated that the control (soybean) tofu had significantly higher yield and textural characteristics than all the different coagulated kenaf seed tofu. Likewise, the coagulant types significantly affected the yield, crude protein, ash, carbohydrate and TPA (hardness, chewiness, springiness and cohesiveness) of the kenaf seed tofu. Among the four different coagulants used to produce the kenaf seed tofu, glucono-delta-lactone was the best coagulant, followed by aluminium potassium salt. In contrast, calcium sulphate produced tofu of least yield, hardness, chewiness, springiness, cohesiveness and crude protein content. Therefore, it is recommended that glucono-delta-lactone or aluminium potassium salt should be used to produce kenaf seed tofu.

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