



## Investigation of the Effect of Additives on the Texture of *Amorphophallus* Sp. Noodles

Afiqa Nabihah Ahmad Zaini<sup>1</sup>, Mazura Jusoh<sup>1,2,\*</sup>, Zaki Yamani Zakaria<sup>1</sup>, Yanti Maslina Mohd Jusoh<sup>1</sup>, Mohamad Sukri Mohamad Yusof<sup>1</sup>, Dayang Norulfairuz Abang Zaidel<sup>3</sup>, Norzita Ngadi<sup>1</sup>, How Chee Yang<sup>1</sup>

<sup>1</sup> Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Malaysia

<sup>2</sup> Centre of Lipids Engineering and Applied Research (CLEAR), Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Malaysia

<sup>3</sup> Faculty of Malaysia-Japan International Institute of Technology (MIIT), Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia

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### ABSTRACT

Konjac noodles, which are derived from *Amorphophallus muelleri* flour (AMF), are a promising functional food due to their high dietary fiber content and health benefits, including cholesterol regulation and glucose control. However, their acceptance is limited by poor textural characteristics such as excessive chewiness and weak structure. This study aims to investigate the effects of two specific additives, which are calcium hydroxide and psyllium husk, on the textural properties of AMF-based noodles, focusing on firmness, springiness, and toughness. The noodles were prepared using a 1:10 ratio of konjac flour to water, with various concentrations of calcium hydroxide (0.01%, 0.02%, 0.03%) and psyllium husk (0.1%, 0.2%, 0.3%) (w/w). Texture profile analysis (TPA) showed that calcium hydroxide significantly enhanced firmness, while psyllium husk improved springiness and overall chewiness of noodles. The findings revealed that using 0.01% calcium hydroxide and 0.2% psyllium husk enhances the texture of konjac noodles, which increases firmness (784.96 g), moderate springiness (11.89%), and high toughness (5607 g-s). This combination of both additives produced a synergistic effect, producing a texture similar to conventional wheat-based noodles while retaining the health benefits of konjac. The findings highlight that optimizing additive levels can improve the sensory and structural quality of konjac-based functional foods.

## 1. Introduction

The rising global demand for functional and healthier food products has led to the development of konjac-based noodles, which are produced from the corms of *Amorphophallus sp.*, a genus recognized for its high konjac glucomannan (KGM). KGM consists of high dietary fibre content, compared to traditional noodles, which are often made with refined wheat flour that has a low nutritional fibre level since the milling process removes the bran and germ, which are the key sources of fibre. Among its various species, *Amorphophallus muelleri* stands out for its abundance in Southeast Asia and Malaysia, where it is both easy to cultivate the glucomannan content compared

\* Corresponding author.

E-mail address: r-mazura@utm.my

to the more widely researched *Amorphophallus konjac* [1]. Both plants belong to the same botanical family, the *Araceae* family, and have similar gelling and water-absorbing abilities, which make them great candidates for the development of low-calorie and high-fiber konjac-based noodles [3]. There are a few common varieties of *Amorphophallus* sp. corms used to produce commercial konjac flour, such as *Amorphophallus muelleri* [2], *Amorphophallus konjac*, and *Amorphophallus bulbifer* [4]. A comparison of the species is shown in Table 1.

**Table 1**  
Comparison of *Amorphophallus* sp.

Species	Description	Reference
<i>Amorphophallus muelleri</i>	Konjac glucomannan (KGM) ranges between 60% to 65%. Native to Southeast Asia, mostly in Indonesia.	[2]
<i>Amorphophallus konjac</i>	Has lower KGM content than <i>A.muelleri</i> , contains glucomannan range of 40% to 50%. Native to East Asia, mostly in China and Japan.	[2]
<i>Amorphophallus bulbifer</i>	Has a high KGM content range between 35% to 65%.	[4]

The species used in this study is *Amorphophallus muelleri* (*A.muelleri*), due to its high glucomannan level and being the most abundant species locally. Besides, it is one of the species that is easy to obtain in Malaysia [5]. Konjac noodles are gaining popularity as a healthy meal option since it is gluten-free and a low-calorie alternative to traditional wheat-based noodles [3]. Since there are consumers who are intolerant of gluten, the need for gluten-free noodles is growing rapidly. Typically, Asian nations like China, Japan, Thailand, and Indonesia are producers of konjac tubers [2]. Numerous studies have confirmed the functional benefits of konjac glucomannan, including lowering cholesterol and blood glucose levels, promoting satiety, and improving gut health since it consists of high soluble dietary fiber [6,7]. However, despite its nutritional advantages, konjac-based noodles, which are particularly made from *A. muelleri*, have several problems, in terms of their weak gel structures, excessive chewiness, and limited elasticity. These problems have negatively affected their texture and consumer appeal [2,8].

To address these shortcomings, two specific additives, which are calcium hydroxide and psyllium husk, have been used as a binding agent and softening agent, respectively, to investigate the effectiveness on the texture of konjac-based noodles [9,10]. Psyllium husk, a natural soluble fiber derived from *Plantago ovata*, is well-recognized for its ability to enhance the smoothness and elasticity of food textures [12]. Psyllium husk contains both soluble and insoluble dietary fibers that have high gel-forming capabilities and high capacity for water absorption [13].

The texture of konjac noodles was analyzed using the texture profile analysis (TPA) method with a texture analyzer equipped with a specific probe [14]. TPA is widely used to quantify parameters such as hardness, cohesiveness, springiness, and chewiness, where these attributes provide valuable insight into the structural behavior of gel-based food products like konjac noodles [15]. Since research on developing noodles from this source remains limited, this study aims to investigate the effects of two specific additives, which are calcium hydroxide and psyllium husk, on the textural properties of noodles made from AMF using TPA as the primary evaluation method.

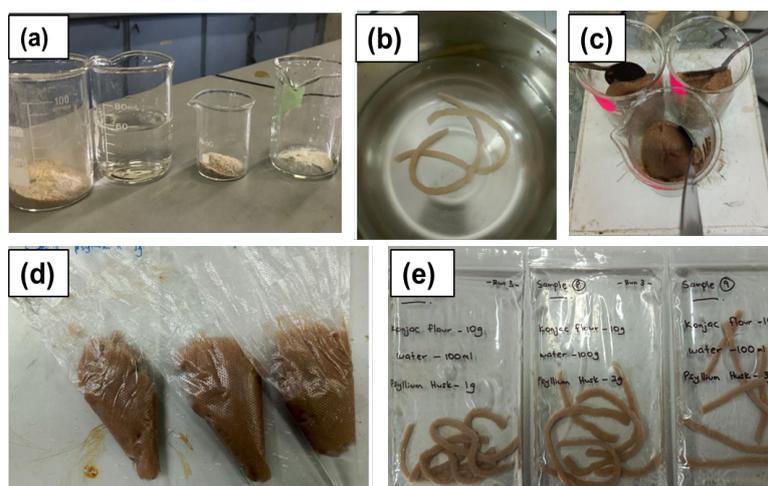
## 2. Materials and Methods

The *Amorphophallus muelleri* flour (AMF) was purchased from a local farm in Negeri Sembilan, supplied by Ladang Konjak Sdn Bhd, which was made from the *A. muelleri* species. The additives used

were food-grade calcium hydroxide and psyllium husk, purchased from Take It Global Sdn Bhd and BioCare Sdn Bhd, respectively. A piping bag was used to shape the konjac noodles.

## 2.1 Konjac Noodles Preparation

Fig. 1 shows the preparation of the konjac noodles process from AMF with the addition of additives. In this study, the formulation of konjac noodles was prepared with a slight modification to a method described in a previous study [14]. Different concentrations of calcium hydroxide (0.01%, 0.02%, and 0.03%) and psyllium husk (0.1%, 0.2%, and 0.3%) were incorporated into the konjac flour, while the flour-to-water ratio was kept constant at 1:10 (w/w) for all samples. The process involved mixing konjac flour, water, and additives for about three minutes to achieve a uniform blend, as shown in Fig. 1(a). Following this, the dough mixture is heated for about three minutes until a bulk solid is formed, as shown in Fig. 1(c). After resting, the dough was placed in a piping bag with a 7 mm nozzle and extruded into noodle strands approximately 3 mm wide and 20 cm long, shown in Fig. 1(d). Then, the noodles were cooked in boiling water for five minutes to set the texture, as in Fig. 1(b) and then stored in sealed bags with distilled water to retain moisture before further analysis, as in Fig. 1(e).



**Fig. 1** (a) preparation of ingredients, (b) noodles in boiling water, (c) heating the dough mixture, (d) dough into a piping bag and (e) storing the cooked noodles

## 2.2 Textural Properties

The texture profile analysis (TPA) of cooked konjac noodles was determined by using a TA-TX plus texture analyzer (Stable Micro Systems Ltd., UK) equipped with the Texture Expert software. The texture of the noodles produced was analyzed in terms of firmness, springiness, and toughness. The cooked konjac noodles were measured at ambient temperature (24°C). The tensile strength of the cooked noodles was determined by using spaghetti/noodle tensile grips (A/SPR) [15]. The test and pre-test speeds were both set at 1.0 mm/s, while the post-test speed was adjusted to 10.0 mm/s. For the measurement of the texture of the noodles, the test mode was set to compression, with speeds of 2.00 mm/sec, and a delay between compressions was 5 secs [15]. The probe with a diameter of 5 cm was used to compress 50% of the konjac noodles twice from their original height.

### 3. Results and Discussion

The results from this work will be presented sequentially, where the effects of each additive will be discussed first. This will be followed by the textural analysis for a few combinations of the concentrations of the additives used, which are calcium hydroxide and psyllium husk.

#### 3.1 Effects of Calcium Hydroxide

In konjac noodle production, calcium hydroxide is essential for forming and stabilizing the glucomannan gel network from *Amorphophallus muelleri* flour (AMF). Table 2 presents the texture parameters of konjac noodles made with different concentrations of calcium hydroxide. At a low concentration (0.01%), calcium hydroxide produced noodles with very high firmness (1258.01 g) and toughness (3916 g·s), but low springiness (2.02%). Calcium hydroxide enhances noodle firmness by promoting cross-linking among glucomannan polymers [16]. It neutralizes acidic groups in glucomannan, strengthening molecular interactions and forming a denser gel network [17]. Calcium ions that are released from calcium hydroxide interact with glucomannan in konjac flour, promoting the formation of a stable gel network [9]. The deacetylation process enhanced the formation of junction zones by enabling hydrogen bonding interactions [17]. When calcium hydroxide concentration increased to 0.02% and 0.03% as shown in Fig. 2, springiness rose (57.67% and 48.61%, respectively), but firmness and toughness decreased. The high springiness value may be due to the loss of acetyl groups from KGM chains by adding an alkaline solution, called deacetylation [9]. This supports previous research [10], which found that calcium hydroxide enhances the tensile strength and hardness in konjac buckwheat noodles through calcium ion interactions that stabilize the gel network. This suggests that while higher calcium hydroxide levels can increase flexibility, they may weaken the gel's overall strength and structure [8]. Overall, research on konjac noodles suggests that low concentrations of calcium hydroxide (0.01%–0.02%) provide the best balance of firmness and springiness, since higher levels can make the noodles too hard or brittle [10].

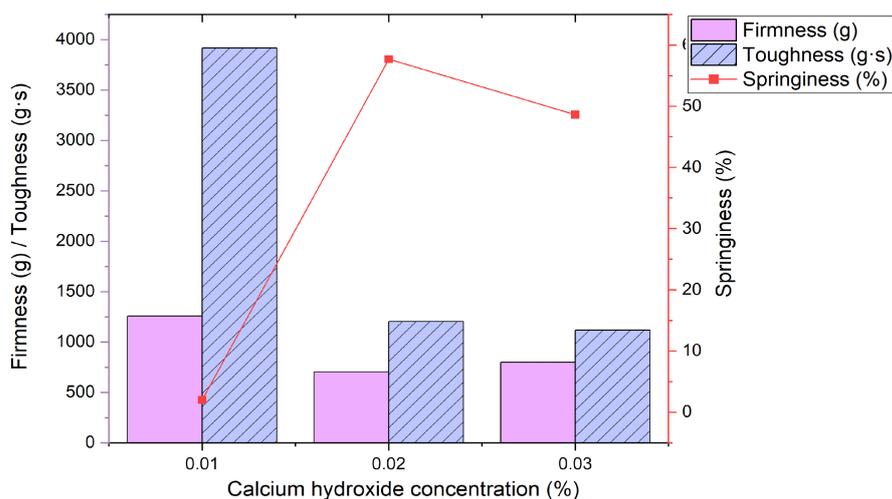
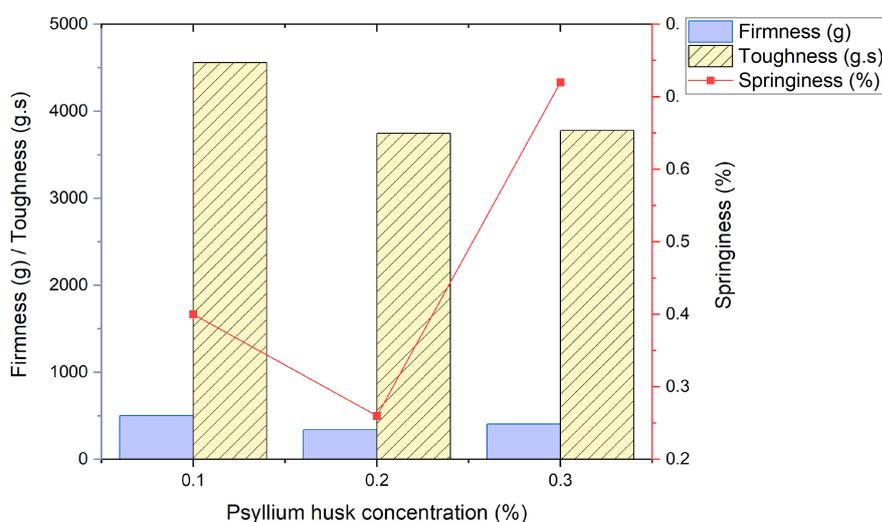


Fig. 2. Texture of konjac noodles at different concentrations of calcium hydroxide

### 3.2 Effects of Psyllium Husk

Psyllium husk contains a high proportion of soluble fiber, mainly 55% to 60% of arabinoxylans, which are primarily responsible for its ability to form gels [18]. When hydrated, the psyllium husk absorbs water and swells, which increases viscosity and produces a gelatin-like mass that can strongly influence the rheological behavior of food systems [12]. Table 2 shows the values of firmness, springiness, and toughness of konjac noodles using different concentrations of psyllium husk. When psyllium husk is added at low concentration (0.1%), it significantly improves toughness (4558 g·s) by strengthening the gel network through mechanisms such as hydrogen bonding and enhanced water retention [18]. Conversely, as the concentration of psyllium husk increased from 0.1% to 0.2% as shown in Fig. 3, the firmness decreased notably (504.87 g and 339.79 g, respectively). This trend indicates that higher fiber content may interfere with the formation of a cohesive gel network, resulting in softer textures [12]. Several previous studies on noodle production have demonstrated psyllium husk's ability to improve firmness at relatively low concentrations. In pea protein gel systems, a 2.0% psyllium husk concentration achieved optimal hardness ( $1.19 \pm 0.02$  N), showing a dose-dependent improvement [18]. Similarly, in composite wheat flour noodles, adding 10% psyllium husk increased hardness to  $18.3 \pm 0.24$  N, showing greater firmness with higher substitution levels [11]. Low concentrations of psyllium husk generally maintain or slightly improve the springiness of konjac noodles due to the hydrated gel network, retaining elasticity so the noodles bounce back after compression [18]. Hence, for a balanced konjac noodle texture with optimal firmness, springiness, and toughness, using 0.2% concentration of psyllium husk is ideal. This combination maximizes gel strength and resilience without compromising the elasticity.



**Fig. 3.** Texture of konjac noodles at different concentrations of psyllium husk

**Table 2**

Texture parameters of konjac noodles at different concentrations of calcium hydroxide and psyllium husk

Textural parameter	Concentration of calcium hydroxide (%)			Concentration of psyllium husk (%)		
	0.01	0.02	0.03	0.1	0.2	0.3
Firmness (g)	1258.01	702.68	797.26	504.8	339.79	403.74
Springiness (%)	2.02	57.67	48.61	0.40	0.26	0.72
Toughness (g.s)	3916	1204	1117	4558	3749	3779

### *3.3 Textural Interactions*

The texture of konjac noodles is significantly influenced by the combination of calcium hydroxide and psyllium husk, which work together to influence firmness, springiness, and toughness of noodles. Calcium hydroxide promotes the alignment of glucomannan polymers and supports the gel formation by adjusting the pH and strengthening intermolecular interactions, resulting in a stronger and more uniform gel network [16]. Meanwhile, for psyllium husk, which is rich in soluble fibers, absorbs water and produces viscous gels that integrate with the konjac matrix, thereby improving flexibility and water retention [12,18]. When both additives are combined, they act complementarily. Results from Table 2 can be concluded, using low concentrations of calcium hydroxide (0.01%) and low concentrations of psyllium husk (0.2%) can produce better results for producing konjac noodles.

### *3.4 Texture Profile Analysis of Cooked Noodles*

Texture is one of the most important parameters in noodles. Texture parameters, including firmness, springiness, and toughness, were analyzed to determine the most balanced and acceptable formulation. Table 3 shows the overall results of the texture parameter of the konjac noodles produced from two different additives, calcium hydroxide and psyllium husk. Firmness refers to the resistance of a food product to deformation when a force is applied and is typically measured as the peak force required to compress or deform the food item [15]. Based on Table 3, the firmness varied significantly across all of the samples. For instance, adding a low concentration of calcium hydroxide (0.01%) in Sample 1 resulted in significantly higher firmness (1258.01 g), compared with using higher concentrations, which are 0.02% (702.68 g) in Sample 2 and 0.03% (797.26 g) in Sample 3. However, excessive firmness may adversely affect the overall texture of konjac noodles, which can lead to a hard texture, while lower firmness can lead to an overly soft texture and unpleasant taste [16]. Among all samples, Sample 8 shows an optimal firmness value (784.96 g), as it falls within a moderate range, which is neither excessively high nor too low compared to the other samples.

Springiness is the ability of a food product to return to its original shape after being deformed [15]. The addition of calcium hydroxide at low levels significantly enhanced noodle springiness. Based on Fig. 2, incorporating 0.01% of calcium hydroxide resulted in a positive springiness value (2.02%), demonstrating a marked improvement compared to other formulations. Noodles are considered good quality if they show a high value of springiness and cohesiveness, which generally more resistant to physical stress and less likely to break easily [14]. Next, toughness is defined as the energy required to deform a food product until it breaks [15]. As the concentration increased to 0.02% and 0.03%, the value of toughness rose to 1204 g·s and 1117 g·s, respectively. This finding is supported by a previous study [9], which examined the rehydration and texture of dried konjac noodles using different alkaline and gelling agents. The study reported that noodles treated with calcium hydroxide showed higher springiness and cohesiveness than those treated with sodium alginate. Hence, Sample 8 with a 1:10 konjac flour to water ratio, 0.01% calcium hydroxide, and 0.2% psyllium husk, demonstrated an optimal combination of moderate firmness, sufficient springiness, and high toughness, making it the most suitable formulation for konjac noodles in terms of desirable texture, compared to other samples. This combination suggested that the noodle is chewy, durable, and pleasant to bite, which is ideal for consumer acceptance, even though none of the samples reach the standard firmness or springiness values reported in previous studies for konjac noodles [9,10].

**Table 3**  
 Texture of konjac noodles at various formulation combinations

Sample	Formulation (Konjac flour: water: calcium hydroxide: psyllium husk) (g)	Firmness (g)	Springiness (%)	Toughness (g-s)
1	1: 10: 0.01: 0	1258.01	2.02	3916
2	1: 10: 0.02: 0	702.68	57.67	1204
3	1: 10: 0.03: 0	797.26	48.61	1117
4	1: 10: 0: 0.1	504.87	0.40	4558
5	1: 10: 0: 0.2	339.79	0.26	3749
6	1: 10: 0: 0.3	403.74	0.72	3779
7	1: 10: 0.01: 0.1	1007.66	12.95	8336
8	1: 10: 0.01: 0.2	784.96	11.89	5607
9	1: 10: 0.01: 0.3	750.53	22.58	3631

#### 4. Conclusion

The study indicates that achieving the ideal texture of konjac noodles depends on balancing the amounts of calcium hydroxide and psyllium husk. The findings revealed that using 0.01% calcium hydroxide and 0.2% psyllium husk (Sample 8) enhances the texture of konjac noodles, which increases firmness (784.96 g), moderate springiness (11.89%), and high toughness (5607 g-s). This suggests that a moderate inclusion of psyllium husk together with calcium hydroxide is key to optimizing the noodle quality. This addition formulation suggests a synergistic effect between the cross-linking capability of calcium hydroxide and the gel-forming properties of psyllium husk, leading to improvement of the noodles' quality. As recommendations for future research, exploration of new additives like plant-based gums or fibers to improve texture and firmness can be studied further. Consumer acceptance testing or sensory tests should also be carried out to ensure the noodles meet the market preferences.

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