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Research Article

GERMINATED BAMBARA GROUNDNUT MANUFACTURING BY HOT AIR FLUIDIZED BED DRYING TECHNIQUE

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ABSTRACT:
The paper aims to study the manufacturing of germinated bambara groundnut by hot air fluidized bed drying (HA) technique. The desirable moisture content was 13-15% (dried basis). The suitable germination method and the minimum superficial air velocity of fluidization (V_{min}) were determined. The drying kinetics of HA (90, 130 and 150°C) were compared with sun drying (SD). Moreover, the dried product qualities, i.e. the microorganism quantity, GABA content, color and the consumer satisfaction, were also studied. Study results showed that the germination from unshell bambara groundnut (UBG) got the maximum value of germination rate and *GABA content. The microorganism quantities after germination were higher than 7,000,000 CFU/g. The V_{min} was 15.8 m/s. The HA had the higher drying rate than SD and could decrease the microorganism quantities to the safety level. The GABA content significantly changed after HA above 130°C. The germinated UBG color after HA was darker than the commercial groundnut. The consumer satisfied the odor, color and the texture of the germinated UBG after HA at 130 and 150°C.*

Keywords: *Germinated bambara groundnut, Fluidization, GABA, Microorganism, Consumer satisfaction*

1. INTRODUCTION

South of Thailand has much bambara groundnut farms that are widely grown in the rubber plantation. It makes the additional income for the agriculturist. The bambara groundnut (BG) has many nutrients such as a carbohydrate (63%), protein (19%), oil (6.5%), etc [1,2]. Presently, the BG takes to use producing flour, an ingredient in cooking or eaten as snack owing to the high amount of carbohydrate and protein [3]. Many researchers studied to find the development method the nutrition within cereal grain. The germination method is a way that could increase the nutrition. Sunte et al. [4] investigated the effect of the soaking and germinating process on GABA content in brown rice. They found that the germination process at a soaking temperature of 40°C for 36 hours caused the increase of maximum GABA content about 9.2 times in comparison with brown rice before germination. Khampang et al. [5] reported that the increased nutrients inside nuts after through the germination process. Those nutrients were the carbohydrate, vitamin B1, phenolic, and especially γ-amino–butyric acid or GABA. GABA is a free amino acid which good for health particularly blood pressure reduction in the brain and the growth inhibition of cancer cell [6,7]. However, the germination process causes the increase of microorganism quantities [8]. Thus, after germination, the germinated bambara groundnut needs to be treated in order to decrease the number of microorganisms. The decrease of the amount of microorganism could perform by many methods such as using steaming, chemical eradication and high temperature drying [9,10]. The hot air fluidized bed drying (HA) at high

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temperature is employed in this study. The HA could rapidly decrease the moisture content due to the high heat and mass transfer rate between the drying material and drying medium. Furthermore, the high drying temperature will annihilate the microorganisms. Nonetheless, the high drying temperature in HA may affect the qualities of drying material after drying such as texture, nutrient [10] and color.

Hence, the objective of this study was the investigation of germinated bambara groundnut manufacturing using hot air fluidization technique. Study results showed regarding the minimum superficial velocity of fluidization (V_{min}), the effect of germination method on the percentage of germination, drying kinetic, the amount of microorganism, GABA content, color of germinated bambara groundnut and the germinated bambara groundnut satisfaction of the consumer.

2. EXPERIMENTAL SETUP

2.1 Materials

In this study, bambara groundnut (BG) used Songkla 1 variety that cultivated in Songkla province, Thailand. It harvested in November 2014.

2.2 Preparation of germinated bambara groundnut

BG was cleaned by water for clay elimination at surface BG. After that, the BG was selected by visualization and soaking in water for separation the complete BG and incomplete BG. The incomplete BG was lean and small grain. Hence, the incomplete grains floated while the complete grains sank. The full grain of BG used to produce the germinated bambara groundnut in this study. The germination method of BG in this study used in two methods namely the germination from unshell BG (UBG) and BG as shown in Fig. 1(a) and 1(b), respectively. The UBG obtained from the BG which was removed its shell by hand. Both UBG and BG germinated by soaking in water for 72 hours and changing the water every 12 hours. Then, they were incubated in a closed box for 72 hours and opening the box every 24 hours. After germination process, the UBG and BG appeared small bud about 2-5 mm as shown in Fig. 1(c). The percentage of germination of UBG and BG were estimated by visualization. The UBG and BG were randomly selected to count the number of germinated grain. Then, the number of germinated seed was calculated and presented in term of the germination percentage. The percentage of germination results were the average value from three repetitions.

(a) UBG (b) BG (c) Germinated bambara groundnut

Fig. 1. The UBG, BG and germinated bambara groundnut used in the present work.

2.3 Preparation of dried germinated bambara groundnut sample

The germinated bambara groundnut dried in two methods, i.e., the sun drying (SD) and hot air fluidized bed drying (HA). In sun drying, germinated bambara groundnut dried about 8 hours per day. Then, germinated bambara groundnut samples were taken to keep in a desiccator for protecting moisture reabsorption. Hot air fluidized bed dryer consisted of a blower driven by a 2 HP motor; 3 kW heater controlled by a PID controller with an accuracy of ±1°C; a cylindrical drying chamber with an inner diameter 20 cm and a height of 100 cm and an air distributor which was the perforated metal sheet with 15 holes per 10 cm^2. The fluidized bed dryer had the work diagram as shown in Fig. 2. The germinated bambara groundnut dried at drying temperature of 90, 130 and 150°C. These temperatures were mostly used for drying the agricultural product such as germinated rice drying and banana drying [11,12]. A bed height was fixed at 15 cm and a superficial air velocity was set at 16.8 m/s. In experimental operation, the germinated bambara groundnut was fed into the drying chamber at the dryer inlet. The blower drove the air through the heater. The air was heated up to desired drying temperature. Then, the hot air flowed into a

drying chamber to heat and mass transfer with germinated bambara groundnut. The hot air issued out of drying chamber and reused about 80% for mixing with fresh air. The germinated bambara groundnut dried to suitable moisture level about 13-15% (dried basis, d.b.). The germinated bambara groundnut samples kept in cold storage at 4-6°C before the quality test. The germinated bambara groundnut qualities showed concerning microorganism quantities, GABA quantities, the color of germinated bambara groundnut and the germinated bambara groundnut satisfaction of the consumer. Results of the minimum superficial air velocity of fluidization (V_{min}) and drying kinetic represented by the average value of three replications.

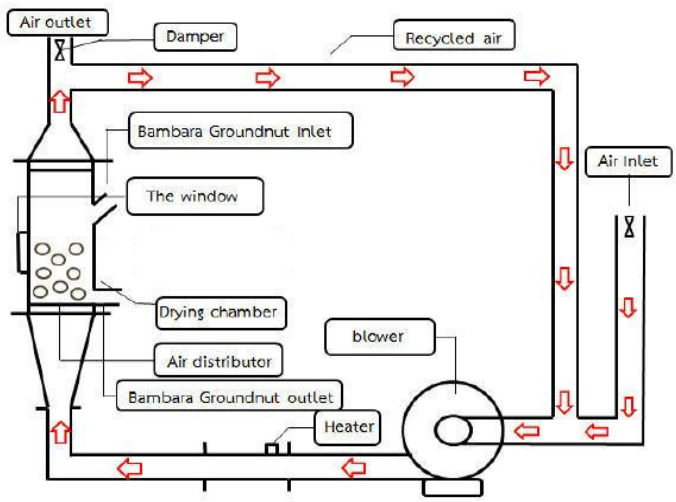


Fig. 2. Schematic diagram of germinated bambara groundnut drying by hot air fluidized bed dryer.

2.4 Detection of the quantities of microorganisms

The germinated bambara groundnut sample was pulverized into the flour using a Tekmar Stomacher 80 pulverizer (American Instrument Exchange, Haverhill, MA). Then, flour was sieved using the 80-mesh screen. 50 g flour mixed with 450 mL Butterfield's phosphate-buffered dilution water in a blender jar for 2 min. The blended solution around 1 mL dropped onto three plates. Subsequently, the plate count agar of 12–15 mL was added and blended with the blended solution on the plates. The plate count agar was hardened by cooling. A plate was turned over and incubated punctually at 35°C for 46-50 hour. During incubation, the microorganisms were not growth. After incubation, the number of the colony of microorganisms was counted. The method for this microorganisms detection referred in the Bacteriological Analytical Manual [13]. Quantities of microorganisms were the average value from three replications.

2.5 Color measurement of germinated bambara groundnut

The spectrophotometer (Konica Minolta Chroma Meter CR-400) with a D65 illuminant was used to measure the color of germinated bambara groundnut. The color descriptor was the CIE L* a* b* color scale. The value of L* a* b* displayed the lightness-blackness, redness-greenness, and yellowness-blueness, respectively. The colorimeter calibrated with a standard white plate before the color measurement of germinated bambara groundnut. The germinated bambara groundnut grains were randomly selected and put into a glass sample cup. Then, the color of germinated bambara groundnut grain was inspected. Results of color measurement presented in the form of the average value which obtained from ten individual duplicates of each experiment.

2.6 Detection of GABA quantities

The amounts of GABA within germinated bambara groundnut measured by using High-Performance Liquid Chromatography (HPLC). The germinated bambara groundnut samples were pulverized into flour, and they were changed into the solution before the test by HPLC. The germinated bambara groundnut flour about 0.5 g mixed with 200 µl sulfosalicylic acid and 1.8 ml water. All ingredients thoroughly mixed by vortex machine. The supernatant in the solution was separated by centrifuge at 4200 rpm/min for 10 min. Subsequently, the remained solution was analyzed by HPLC. The analysis of GABA content performed by the method proposed by Knecht et al. [14] and Lin et al. [15].

2.7 Satisfaction assessment of consumer on odor, texture and color of germinated bambara groundnut

The qualities of germinated bambara groundnut in terms of odor, texture and color evaluated from the sensory of the consumer. The consumer about 50 persons tasted germinated bambara groundnut samples and assessed those qualities by the answer in the questionnaire. The questionnaire results evaluated and presented by score level as follows: 3.50 (very good), 3.00-3.49 (good), 2.50-2.99 (fair), 2.00-2.49 (poor) and less than 2.00 (very poor).

2.8 Statistical analysis

Experimental data were analyzed to show the significant difference in quality among treatments by the analysis of variance (ANOVA) using SPSS software (SPSS, Version 19, Inc., an IBM Company). The results represented as mean values ± standard deviations (SD). Differences between mean values were established using Duncan's multiple range tests at a confidence level of 95% ($p \leq 0.05$).

3. RESULTS AND DISCUSSION

3.1 Effect of germination method on the percentage of germination and the drying kinetic of sun drying

The percentage of germination of UBG and BG showed in Table 1. The UBG and BG grains started to germinate when they were incubated in a closed box for 24 hours and theirs germination percentage were not different; the percentage of germination was approximately 7%. When the incubation time was taken longer, the percentage of germination between both samples increased and was distinctly different. The percentage of germination of BG was significantly lower than that of UBG. The lower germination percentage for BG due to the BG had a too high moisture content as shown in Fig. 3, leading to the large amounts of microorganism and resulting in the spoiled grains. Moreover, the BG shell might obstruct the movement of water into the kernel and affected the growth stimulation within the kernel.

Table 1: The relationship between the percentage of germination and the incubation time

Incubation time (hours)	Percentage of germination	
	UBG	BG
0	0	0
24	7±1.41	6.5±0.71
48	37±2.83	11±1.41
72	93±2.83	12±0.00

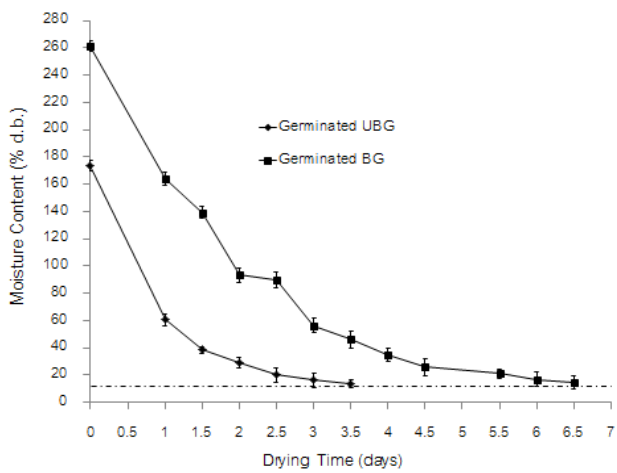


Fig. 3. The evolution of moisture content of germinated UBG and germinated BG during SD drying.

Figure 3 shows the changes in the moisture content of germinated grains obtained from UBG and BG during SD drying. After the germination process, UBG and BG had an initial moisture content of 173.58 and 261.37% (d.b.), respectively. The higher initial moisture content of BG involves the shell that can absorb the moisture, leading to higher moisture content. When the germinated grains dried, theirs moisture content reduced rapidly in the early period of drying in the first two days of drying. This decrease is because the moisture existing in the samples stays

at the sample surface so that their moisture content can be vaporized rapidly [16]. When the drying time was taken longer, the drying reduced gradually due to the diffusion of moisture from internal to grain surface. As shown in Fig. 3, the required drying time at 13-15% (d.b.) for UBG was taken shorter than BG. From the results of the percentage of germination in Table 1 and the drying kinetic results in Fig. 3, it indicated that the germination from unshell BG (UBG) was appropriate for germination and drying. Hence, it was selected for the subsequent study.

3.2 Minimum fluidization velocity

The effect of superficial air velocity on pressure drop across bed at the bed depth of 15 cm by increasing air velocity from the fixed bed state showed in Fig. 4. It found that the growth of superficial air velocity led to the rise of pressure drop across bed. The superficial air velocity of 15.87 m/s provided the highest pressure drop across bed. It indicated that this air velocity is the minimum fluidization velocity. Minimum fluidization velocity obtained when the pressure drop across the bed is supreme [17]. The further increase in the air velocity, the pressure drop reduces slightly. Fig. 5(a) and 5(b) showed the movement behavior of germinated UBG at superficial air velocities of 11.78 and 15.87 m/s, respectively. At air velocity of 11.78 m/s, the air velocity is not enough for the formation of fluidization state as shown in stationary bed state. The fluidization state initially occurred at the air velocity of 15.87 m/s as indicated by the movement of germinated UBG grain in the drying chamber.

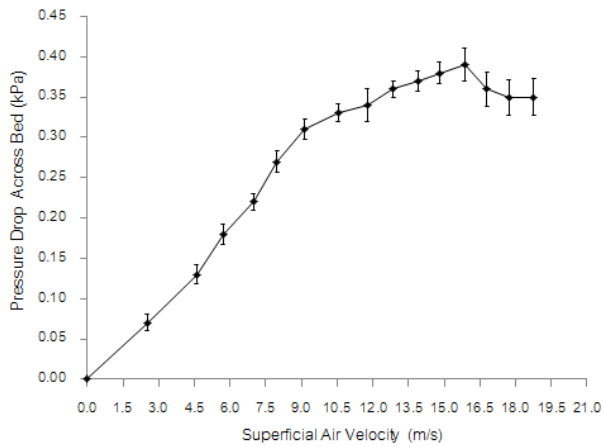
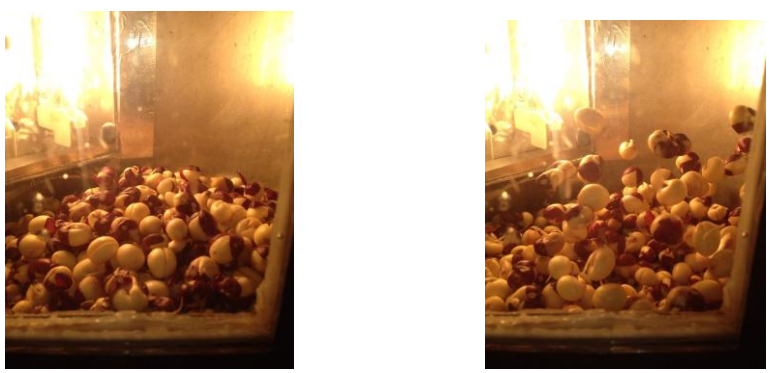


Fig. 4. The relationship between pressure drop and superficial air velocity at bed depth of 15 cm.



(a) 11.78 m/s (b) 15.87 m/s

Fig. 5. Germinated UBG at superficial air velocity at 11.78 m/s and 15.87 m/s.

3.3 Drying kinetic of hot air fluidized bed drying

Fig. 6 shows the changes in the moisture content of HA-dried germinated UBG at bed depth of 15 cm, superficial air velocity of 16.8 m/s and different temperatures. It found that the drying curves of germinated UBG were similar for all drying temperatures; the moisture content was decreased throughout the drying time for all drying temperatures and the drying temperature significantly affected the changes of a moisture content of germinated UBG; the higher drying temperature provided, the greater changes of moisture content. To obtain the moisture content of 13-15% for drying temperatures of 90, 130 and 150 °C, it required 38, 50 and 170 minutes, respectively.

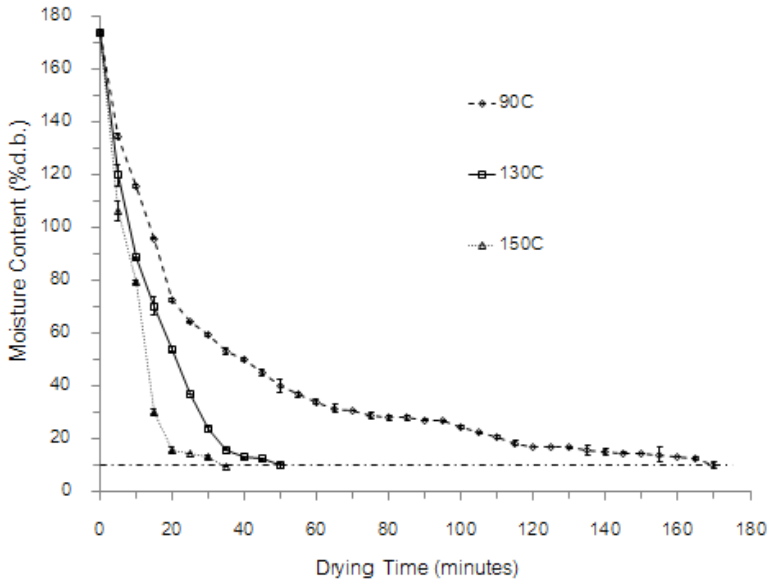


Fig. 6. The evolution of moisture content of germinated UBG using HA drying.

3.4 The quantities of microorganisms

Table 2 shows the microorganism quantities of germinated UBG dried at different methods and temperatures. Before drying, both germinated samples had a large number of microorganisms; the number of microorganisms was about 7.55-7.85×10^6 CFU/g. When they were dried by SD, the number of microorganisms significantly decreased when compared with that of germinated samples without drying. However, the microorganism quantities were higher than the safe level of consumption based on the Thai Industrial Standards Institute, which should not be greater than 10^4 CFU/g for snacks [18]. In the case of HA drying, the number of microorganisms significantly decreased when compared with that of germinated samples without drying, and germinated samples dried by SD. Also, the HA drying can reduce the microorganism quantities to be lower than the safe level of consumption. Also, the microorganism amounts of germinated UBG insignificantly changed with the drying temperature over the temperature range of 90°C to 150°C.

Table 2: Microorganisms amounts of germinated bambara groundnut at different conditions

Sample	Microorganisms quantities (CFU/g)
Germinated UBG without drying	7550000 ± 70710a
Germinated BG without drying	7850000 ± 60710a
SD-dried germinated UBG	155000 ± 3710b
SD-dried germinated BG	195000 ± 5710b
HA-dried germinated UBG at 90°C	440 ± 14c
HA-dried germinated UBG at 130°C	205 ± 7c
HA-dried germinated UBG at 150°C	115 ± 21c

a,b,c mean with different scripts in the same column are significantly different ($p \leq 0.05$).

3.5 Colors

Table 3 shows the color of germinated bambara groundnut at various drying condition. Their colors significantly differenced with commercial groundnut, excepting, b* value; the brightness of germinated UBG after drying was less than commercial groundnut as indicated by the lower L* value; the L* value significantly decreased with the increased drying temperature as shown in Fig. 7(a), 7(b), and 7(c). The lower L* value at higher drying temperature may cause the non-enzymatic browning reactions. This reaction resulted in the formation of yellowish pigments and resulted in dark grain color [19]. The value of a* and b* increased with the elevated drying temperature, particularly, at a temperature of 130 and 150°C. These increased values displayed the grain color of reddish yellow as shown in Fig. 7(b) and 7(c). However, the difference color of samples compared with commercial groundnut at these temperatures was still accepted for consumer as shown in section of 3.7.

Table 3: Color of Germinated UBG at different drying conditions compared with commercial groundnut

Sample	L*	a*	b*
Commercial groundnut	62.36± 0.09c	4.49 ± 0.71a	29.08 ± 0.12c
HA-dried germinated UBG at 90°C	57.85± 0.57b	8.52± 0.71b	26.41 ±0.79a
HA-dried germinated UBG at 130°C	55.42±0.29a	10.44 ± 0.01c	27.44 ±0.44ab
HA-dried germinated UBG at 150°C	54.74± 0.08a	10.49 ± 0.23c	28.24 ± 0.11bc

a,b,c mean with different scripts in the same column are significantly different ($p \leq 0.05$).

(a) 90°C (b) 130°C (c) 150°C

Fig. 7. The color of germinated UBG at 90, 130 and 150°C.

3.6 GABA quantities

Table 4 shows the GABA contents after drying by HA at temperatures of 90, 130 and 150°C. Before germination, the GABA content of UBG was about 28.63±0.10 mg/100 g. This content was relatively larger than that of another grain that has the GABA content such as rice. The GABA contents of Phitsanulok 2 and RD 6 rice were about 2.2±0.1 and 0.9±0.1 mg/100 g as reported by Chungcharoen et al. [20]. When the UBG was germinated, the GABA content was extremely increased. It increased by 5.8 times in comparison with that of UBG. When the germinated sample dried by HA drying at 90, 130 and 150°C, the GABA quantities of germinated UBG sample changed significantly; the GABA content was decreased with increasing drying temperature. These results indicated that drying temperature strongly affected the GABA content. Therefore, the higher temperature of 150°C was not recommended for drying the bambara groundnut.

Table 4: GABA quantities of UBG and Germinated UBG at different drying temperatures

Sample	GABA content (mg/100g)
UBG	28.63±0.10a
Germinated UBG	165.87±1.27e
HA-dried germinated UBG at 90°C	155.37±0.24d
HA-dried germinated UBG at 130°C	138.98±0.08c
HA-dried germinated UBG at 150°C	77.45±1.34b

a,b,c,d,e mean with different scripts in the same column are significantly different ($p \leq 0.05$).

3.7 Consumer satisfaction

The properties of HA-dried germinated UBG regarding odor, color and texture were evaluated and compared. The results of the sensory evaluation presented in Table 5. The HA-dried germinated UBG at 90°C had lower scores on all properties. The HA-dried germinated UBG at 130°C received the highest score in term of odor while the scores of color and texture were highest for the HA-dried germinated UBG at 150°C. However, the sensory qualities of all properties showed the slight difference between HA-dried sample at 130°C and 150°C.

Table 5: Satisfaction score of the consumer for odor, color and texture of Germinated UBG after HA

Sample	Satisfaction score		
	Odor	Color	Texture
HA-dried germinated UBG at 90°C	2.60	3.50	2.22
HA-dried germinated UBG at 130°C	4.16	3.94	3.80
HA-dried germinated UBG at 150°C	4.08	3.98	3.96

4. CONCLUSION

The germination method from UBG was a suitable method for the nutrient development in bambara groundnut; this method gave the high percentage germination and took the short drying time. HA could rapidly decrease the moisture content of germinated UBG; meantime, the GABA still kept the high content, excepting, the higher drying temperature 130°C. The microorganisms quantities decreased to the safety level. Moreover, the color and texture of germinated UBG were greatly enjoyable after drying at 150°C while the odor was extremely satisfied after drying at 130°C. Therefore, germinated bambara groundnut should produce by HA technique at drying temperature of 130°C, which would obtain the overall good qualities of germinated bambara groundnut.

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NOMENCLATURE

BG	bambara groundnut
UBG	unshell bambara groundnut
V_{min}	minimum superficial air velocity of fluidization, m/s
SD	sun drying
HA	hot air fluidized bed drying
GABA	γ-amino–butyric acid
CFU	colony-forming units

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