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Nguyen Phuoc Minh
Tra Vinh University, Vietnam

Correspondence:
Nguyen Phuoc Minh
Tra Vinh University, Vietnam

Effect of different factors in drying water chestnut corm to supplement into functional instant rice powder

Nguyen Phuoc Minh

Abstract
Water chestnut (*Trapa natans* L., *sensu lato*) is an annual, floating-leaved aquatic plant of temperate and tropical freshwater wetlands, rivers, lakes, ponds, and estuaries. After harvest, water chestnut corms rapidly decline in quality due to desiccation, discoloration and pathogen invasion; current storage systems are not conductive for long term storage of the fresh product. Purpose of our research is to investigate different factors affecting to the manufacture of functional instant rice powder supplemented with the dried water chestnut corm. This fortified rice powder is useful to improve nutrition for children living rural and remote area.

Keywords: Water chestnut corms, instant rice powder, nutrition, children.

1. Introduction

In wake of growing demand of the consumers for natural foods having good therapeutic values, water chestnut offers excellent opportunity. The high consumption values of the fresh fruit are probably linked to the high nutritional and organoleptic value, and also to the increasing interest of the consumers towards organic products (Gagan Deep Singh et al., 2010). Water chestnut popularly known as *Nang* in Vietnam, is an aquatic angiosperm. It belongs to the family *Trapaceae*, one of the free-floating plants, grown in shallow water fields, ponds or swampy lands in tropical and sub-tropical countries (Takano and Kadono, 2005). The water chestnut kernel is covered with a thick jet-black outer pericarp shaped like a horn protruding from the head of a buffalo. Its main root system adheres in the muddy soils at the bottom of the pond and it is connected with floating leaves by herbaceous stems in water body. It is grown in Vietnam mainly for human consumption either in the form of vegetable, dried to make flour to prepare flattened bread called chapatti or in the shape of sweet dishes of many kinds according to individual's taste. The kernel is delicious and contains carbohydrates, proteins and essential minerals. It also contains a plentiful B vitamins (including B1, B2, B5 and B6), E, A, and vitamin C. Due to the sweet, tender and delicious taste, cooked water chestnut is one of the popular starchy desserts in Asian countries (Meredith Hummel and Erik Kiviat, 2004).

Majumdar and Jana (1977) and Lee and Hwang (1998) studied physicochemical analyses of water chestnut fruit to provide fundamental data for water chestnut processing and product development. Water chestnut prefers warm and humid environment. The fresh product is minimally processed and therefore maintains a fresh like state. However, minimally processed fresh products have relatively short life because of large amount of tissue disruption and increased metabolism (King and Bolin 1989; Watada *et al.*, 1990; Varogquaux *et al.*, 1996; Paull and Chen 1997), which results in a very rapid onset of enzymatic browning (Buta and Abbott 2000).

Rodrigues *et al.* (1964) studied the processing of water chestnuts and found that canning in 0.1 % citric acid (pH 4.2) and sterilization for 15 min were the best. Treatment with 0.1 M citric acid markedly extended the shelf life, inhibited surface coloration and disease development, and reduced the loss in eating quality associated with the contents of ascorbic acid and total soluble solid, titratable acidity and ascorbic acid (Peng *et al.*, 2004).

Peng and Jiang (2006) investigated the potential usage of salicylic acid as a powerful anti-browning agent in fresh-cut Chinese water chestnut and found that it delayed discoloration, maintained eating quality and reduced or delayed activities of polyphenol oxidase (PPO), peroxidase (POD) and phenylalanine ammonia lyase (PAL), in fresh cut Chinese water chestnut. Our earlier findings encompassed work on water chestnut drying characteristics (Singh *et al.*, 2008), native water chestnut starch (Singh et al., 2009), and modified water chestnut starch (Singh *et al.*, 2009) which will help this important commodity get the required attention from food processors. As water chestnut is available for only 2-3 months in a year and this fruit has to be made available for longer time for food processors, its storage life had to be studied in detailed.

Water chestnuts can be used in a variety of recipes because they have a starchy taste that is fairly neutral. Some people claim that their flavour is similar to a bland nut. Water chestnuts also have a firm and crispy texture, which adds to their appeal as an ingredient in stir-fries, salads, or any meals where the vegetables to be used must have a crunchy consistency (S.K. Garg *et al.*, 2010).

Chinese water chestnut (*Eleocharis dulcis* (Burman f.) Trin ex Henschel) is a corm consumed globally in Oriental-style cuisine. The corm consists of three main tissues, the epidermis, subepidermis, and parenchyma; the cell walls of which were analyzed for sugar, phenolic, and lignin content. Sugar content, measured by gas chromatography, was higher in the parenchyma cell walls (931 µg/mg) than in the subepidermis (775 µg/mg) or epidermis (685 µg/mg). The alkali-extractable phenolic content, measured by high-performance liquid chromatography, was greater in the epidermal (32.4 µg/mg) and subepidermal cell walls (21.7 µg/mg) than in the cell walls of the parenchyma (12.3 µg/mg) (Terri Grassby *et al.*, 2013).

2. Material & Method

2.1 Material

Water chest nut corm is collected in Nga Nam District, Soc Trang province, Vietnam.

Fig 1: Fresh water chestnut corm

2.2 Research method

- Determine some quality criteria in raw material (water chestnut corm) and instant rice powder supplemented by the dried water chestnut corm, including fiber, carotenoid, vitamin C.
- Determine protein, lipid, glucid, dry matter or rice, soybean, greenbean, sesame, powder
- Determine ratio and moisture of the dried water chestnut corm which is supplemented into the instant rice powder.
- Evaluate nutrition and sensory characteristics of instant rice powder.

2.3 Testing method

- Determine vitamin C by Iod titration
- Determine carotenoid by Gost method
- Determine protein by microkjeldahl method
- Determine lipid by Shoxhlet method
- Determine ash by burning
- Determine dry matter by drying to basic weight
- And others

2.4 Statistical analysis

All data are processed by ANOVA (Startgraphics) to check the significant difference via LSD.

3. Result & Discussion

3.1 Nutritional composition in raw material

Table 1: Nutritional composition in raw material

Water chestnut corm	Nutritional composition (%g dry matter)			
	Protein	Lipid	Glucid	Ash
Rice	9.85	1.52	88.18	0.45
Soy bean	39.45	23.5	32.49	4.56
Greenbean	26.14	2.50	68.98	2.39
Sesame	20.55	58.59	17.81	3.06

From table 1, we see the protein content in soy bean, green bean and sesame is quite high so this is the valuable vegetable protein source for children deficienced animal protein. Lipid content in sesame is very high (58.59%) so this is meaningful in nutritional supplementation for children. For water chestnut corm, we analyse some criteria: fiber, vitamin C and carotenoid.

Table 2: Nutritional components in the water cheastnut corm

Component	Fiber (g)	Vitamin C (mg)	Carotenoid (mcg)
Content	2.7	180	9,240

From table 2, nutritional components such as vitamin C and carotenoid in water chestnut corm is quite high. This is a vital vitamin source for children.

3.2 Effect of drying time to moisture content in the dried water chestnut corm

From initial moisture content 80%, drying in 70 ^{0}C; after 130 minutes the moisture remains 30.2%; after 160 minutes the moisture remains 20.1%; after 170 minutes the moisture remains 9.8%.

Table 3: Effect of drying time to moisture in the dried water chestnut corm

Drying time (minutes)	0	40	80	120	130	140	150	160	170	180
Moisture content (%)	80.0	65.0	55.5	32.4	30.2	29.3	23.0	20.1	9.8	8.6

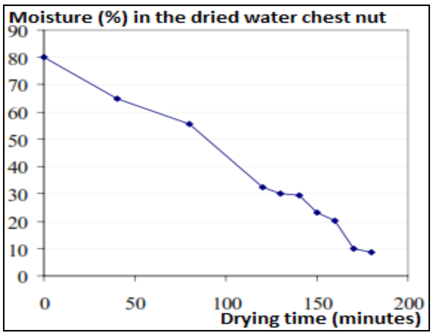

Fig 2: Effect of drying time to moisture in the dried water chestnut corm

3.3 Nutritional components in the dried water chestnut corm
3.3.1 Fiber content in the dried water chestnut corm

Table 4: Fiber content in the dried water chestnut corm

Sample	Drying time (minutes)	Moisture (%)	Fiber content (mg%)
Fresh water chestnut corm	0	80.0	2.70
	130	30.2	7.12
Dried water chestnut corm	160	20.1	9.45
	170	9.8	14.02

From table 4, fiber content in water chestnut corm is very high so it’s ideal to supplement into instant rice powder.

3.3.2 Vitamin C in the dried water chestnut corm

Vitamin C is easily decomposed during processing so we investigate the influence of drying temperature and time to the vitamin C loss.

Table 5: Vitamin C in the dried water chestnut corm during drying

Sample	Drying time (minutes)	Moisture (%)	Vitamin C (mg%)
Fresh water chestnut corm	0	80.0	180.0
	130	30.2	65.0
Dried water chestnut corm	160	20.1	26.1
	170	9.8	4.5

Vitamin C in water chestnut corm is lost dramtically during drying process. With initial moisture 80% and vitamin C 180 mg%, after 130 minutes of drying moisture remained 30.2% and vitamin C remained 65 mg% (lost 64%). The longer drying time is, the more vitamin C looses. Coming to 10% moisture content, vitamin C remained 4.5 mg% (lost 97%).

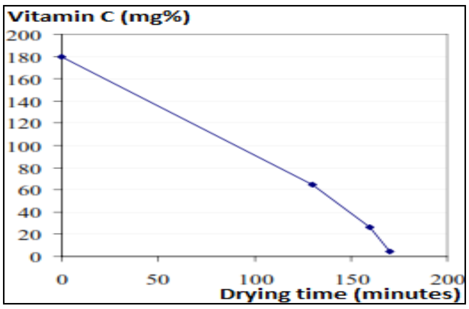

Fig 3: Vitamin C in the dried water chestnut corm during drying

3.3.3 Carotenoid in the dried water chestnut corm

Table 6: Carotenoid and β – caroten in the dried water chestnut corm

Sample	Drying time (minutes)	Moisture (%)	Carotenoid (mcg%)	β – carotene (mcg%)
Fresh water chestnut corm	0	80.0	9,240	4,620
Dried water chestnut corm	130	30.2	8,050	4,025
	160	20.1	6,900	3,450
	170	9.8	6,420	3,210

Drying the dyring process, carotenoid and β – caroten are reduced. Owing to mild drying temperature (70 ^{0}C), the carotenoid loss is not significant.

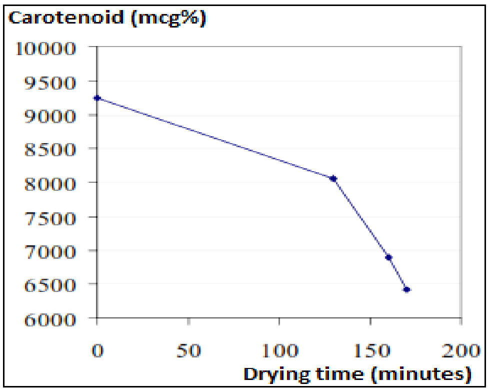

Fig 4: Carotenoid in the dried water chestnut corm during the drying

Table 7: Effect of moisture and ratio of the dried water chestnut corm to the moisture of extrusion

Formula	Moisture of extrusion (%)
CT1-1 (1% corm, moisture 9.8%)	13.2
CT1-2 (1% corm, moisture 20.1%)	13.8
CT1-3 (1% corm, moisture 30.2%)	13.6
CT2-1 (2% corm, moisture 9.8%)	14.8
CT2-2 (2% corm, moisture 20.1%)	14.4
CT2-3 (2% corm, moisture 30.2%)	14.9
CT3-1 (3% corm, moisture 9.8%)	16.7
CT3-2 (3% corm, moisture 20.1%)	16.9
CT3-3 (3% corm, moisture 30.2%)	17.2

3.4 Effect of ratio supplementation and moisture of the dried water chestnut corm to the extrusion

Extrusion is affected by different factors, moisture is crucial to this process. This relates to extrusion temperature, size, swelling and moisture of semi-finished powder. From table 7 & figure 5, in the same ratio of corm, moisture of corm reduces from 30.2% to 9.8%, the moisture of extrusion change insignificantly. So moisture of corm doesn't affect to moisture of extrusion. However, ratio of corm increases from 1% to 3%, moisture of extrusion also increases respectively. So ratio of corm is relevant to moisture of extrusion.

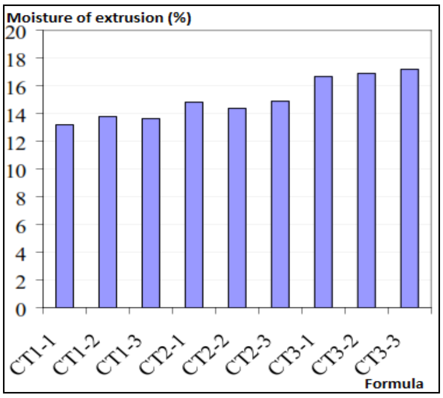

Fig 5: Effect of moisture and ratio of the dried water chestnut corm to the moisture of extrusion

From table 7 and figure 5, CT1-1, CT1-2, CT1-3 and CT2-2 are optimal for extrusion so we decide to choose these formulas for further experiments.

Table 8: Effect of moisture content to extrusion temperature

Formula	Moistutre (%)	Extrusion temperature (°C)
CT1-1	13.2	174
CT1-2	13.8	171
CT1-3	13.6	173
CT2-1	14.8	168
CT2-2	14.4	170
CT2-3	14.9	166
CT3-1	16.7	154
CT3-2	16.9	150
CT3-3	17.2	148

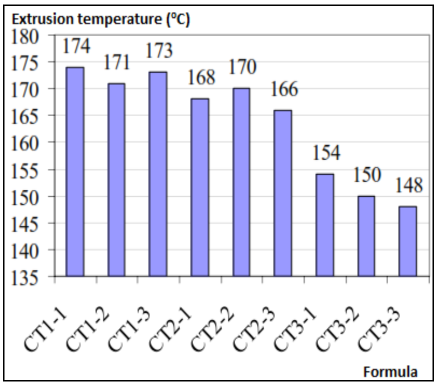

Fig 6: Effect of moisture content to extrusion temperature

3.5 Nutritional components in the instant rice powder samples CT1-1, CT1-2, CT1-3, CT2-2

3.5.1 Fiber in the instant rice powder samples

Table 9: Fiber in the instant rice powder samples

Formula	Fiber (g%)	Acceptable fiber demand for children (%)
CT1-1	4.01	72.98
CT1-2	3.48	63.39
CT1-3	1.70	30.95
CT2-2	3.55	64.57

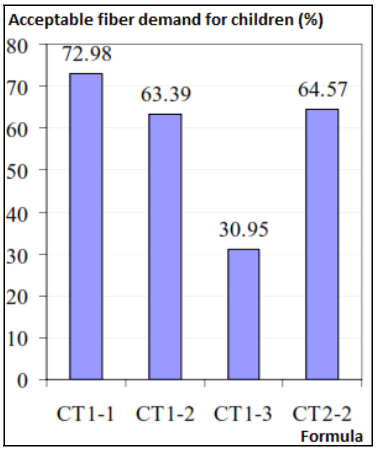

Fig 7: Acceptable fiber demand for children

From table 9 and figure 7, fiber in formula CT1-3 is quite low (1.7g%). Other formulas have fiber content ranging from 3% - 4%. Study from Netsle, the rice powder demand for children at 1-2 years old is about 150g per day. In that demand, fiber needed for children is 6.5 – 7.5g /day/children. With this amount, we can use formulas CT1-1, CT1-2 and CT2-2 to meet 5.25 – 6.00 g fiber/day/ children (average 63% – 73% demand). This level is quite ideal because children can eat other rich fiber food sources.

3.5.2Vitamin C in the instant rice powder

During extrusion at high temperature (70 °C), vitamin C is easily lost. So we conduct the experiment to determine vitamin C for formulas CT1-1, CT1-2, CT1-3 and CT2-2.

Table 10: Vitamin C in the instant rice powder formula

Formula	Vitamin C (mg%)	Acceptable demand for children (%)
CT1-1	2.60	12.07
CT1-2	4.80	22.29
CT1-3	6.60	30.64
CT2-2	6.40	29.71

We see that formula CT1-3 has the highest vitamin C content (6.6 mg%) owing to its short drying time. CT1-1 has the lowest vitamin C content (2.6 mg%). Recommendation from Vietnam food institute, children at ages below 2 years old need 30 – 35 mg vitamin C/day/children. So with the daily average of instant rice powder is 150 g for formula CT1-2, CT1-3 and CT2-2 meets 22.29 – 30.64% children demand; only formula CT1-1 satifies 12.7% children demand.

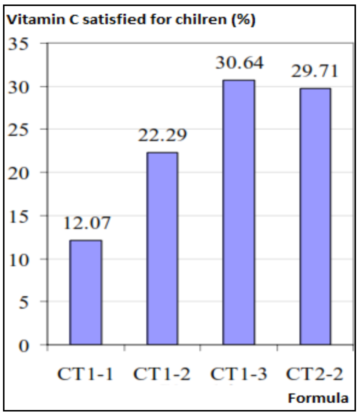

Fig: Acceptable demand of vitamin C for children

3.5.3 Carotenoid in the instant rice powder formula

According to WHO, Vietnam Nutrition Institute; the vitamin A is 375 mcg vitamin A /day. So formula CT1-2 and CT1-3 are satisfied 90% to 94.7% vitamin A demand.

Table 11: Carotenoid in the instant rice powder

Formula	Carotenoid (mcg%)	Vitamin A (mcg%)	Acceptable demand for children (%)
CT1-1	1450	120.8	48.3
CT1-2	2700	225.0	90.0
CT1-3	2840	236.7	94.7
CT2-2	2950	245.8	98.3

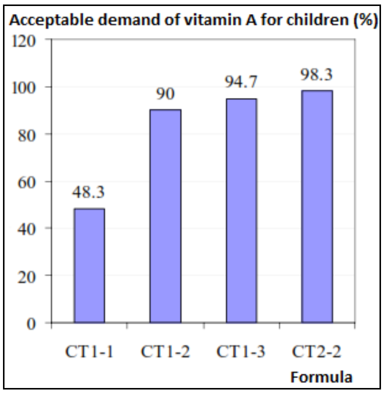

Fig 9: Acceptable demand for vitamin A in children

3.6 Sensory evaluation on powder sample CT1-1, CT1-2, CT1-3 and CT2-2

Table 12: Sensory evaluation on powder sample

Formula	Color	Aroma	Taste	Smoothness
CT1-1	3.70[a]	3.55[a]	3.40[ab]	2.75[b]
CT1-2	**3.95[a]**	**3.60[a]**	**3.40[ab]**	**3.95[a]**
CT1-3	3.40[a]	3.55[a]	3.50[a]	3.25[ab]
CT2-2	3.35[a]	3.10[a]	3.00[bc]	3.45[ab]

With four sensory evaluation, formula CT1-2 (1% the dried water chestnut corm, moisture 20.1%) is highly valued so we can choose 1% dried water chestnut corm to reduce moisture to 20.1% to get the highest powder quality color, taste and feeling.

3.7 Flowing capability of the instant rice powder

Table 13: Effect of water temperature for dissolving the instant rice powder to its flowing capability

Water temperature to dissolve the instant rice powder (°C)	Flowing capab ility (mm/30s)	Com ments
65	75	Less dissolved, particles
60	70	Well dissolved, not attached
55	55	Well dissolved, not attached
50	50	Well dissolved, not attached
45	57	Very well dissolved, not attached
40	14	Well dissolved, not attached

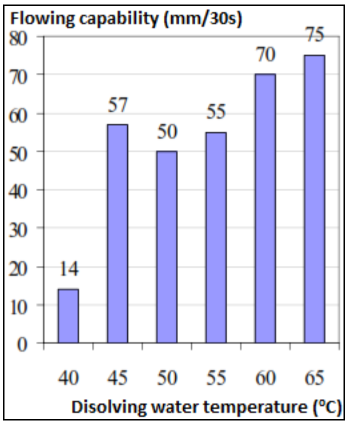

Fig 10: Effect of dissolving water temperature to the flowing capability of the instant rice powder

From table 13 and figure 10, the instant rice powder can dissolve well in 40 – 60 ^{0}C. However at 40 °C, flowing capability is too low (14 mm/30s), while at 60 °C the flowing capability is too high (70mm/30s). These results are not suitable for children because of its condensed or loosed flowing capability. Moreover at 65 ^{0}C, powder has low dissolving capability, and high flowing capability 75 mm/30s so it's also not suitable for dissolving the instant rice powder. The optimal water temperature should be 45 – 55 ^{0}C. At this temperature range, the condensed capability is suitable for children, especially vitamin undamaged by water temperature.

3.8 Nutritional components in the instant rice powder

The instant rice powder CT1-2 is prepared by mixing with some ingredients such as soy bean, sugar, milk, mineral, $CaCO_3$, milk flavour to accomplish the instant powder.

Table 14: Nutriotional components in the instant rice powder

Component	Content (% dry matter)						
	Protein (g)	Glucid (g)	Lipid (g)	Vitamin A (mcg)	Vitamin C (mg)	Fiber (g)	Ash (g)
Value	8.85	78.66	7.68	225.00	4.80	3.71	1.11

4. Conclusion

We primarily examine the dried water chestnut corm supplemented into the functional instant rice powder. If possible, we recommend studying the drying temperature at different levels to effectively eliminate vitamin C loss. Moreover, effect of the preservation time to nutritional value (vitamin C and carotenoid) should also be investigated. A survey of customer preference to evaluate the acceptance is very necessary.

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