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Sensory and Organoleptic Characteristic, Zinc and Iron Content of Fortified Chips from Cassava Flour

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Abstract: Iron fortification can cause several biophysicochemical modifications. Those depend on many factors, such as iron fortificant and the food carrier. There were four groups of chips: 1) non-fortified wheat flour chips (K_1); 2) non-fortified cassava flour chips (K_2); 3) fortified cassava flour chips, each with $ZnSO_4$ 30 ppm and NaFe EDTA (K_3) 30 ppm and 4) fortified cassava flour chips, each with $ZnSO_4$ 50 ppm and NaFe EDTA (K_4) 50 ppm. The chips were evaluated for sensory characteristic (color, taste, flavor, and texture), organoleptic characteristics tested by preference test, as well as zinc and iron contents. Zinc and iron contents were analyzed by Atomic Absorption Spectophotometric method. The results showed that both fortificants did not affect the sensory characteristic of cassava flour chips. The preference test showed that color, taste, and flavor of K_1 chips as a control, were mostly liked, but there was no significant difference preference of texture. Moreover, preference test using K_2 as control showed that color of K_3 was mostly liked, but there was no significant difference preference of taste, flavor and texture. Fortification can increase the contents of zinc and iron in cassava flour chips. The panelist can accept the fortified cassava chips as well as wheat flour chip, as a consequence, both can be a potential way to combat the iron deficiency anemia.

Key words: Fortification, $ZnSO_4$, NaFe EDTA, sensory characteristics, organoleptic, cassava.

1. Introduction

Zinc and iron deficiency are one of the main nutrition problem in Indonesia, especially in the relation to their essential roles in human body [1, 2]. The deficiency of both minerals is related, because both are present in same type of food products. The absorption of both is also inhibited by same inhibitors such as phytate, polyphenols, calcium, and phosphate. Zinc and iron deficiency can affect not only to the children, but also to adults [3, 4].

Food fortification can be taken into account as an effective way to overcome micromineral deficiency. Compared to supplementation program, food fortification is a half less effective [5], but it is less costly. Besides, food fortification can be used for longer time and larger population [6, 7]. In Indonesia, food fortification program has been widely done, especially in wheat flour. The guideline for wheat flour fortification program has been stated in Indonesian Health Ministry Statement No. 1452/Menkes/SK/X/2003. In the other hand, because of not wheat-producing country, Indonesia depends on the other country for providing wheat flour as basic ingredients of biscuits [8]. As a consequence, it is needed to substitute wheat flour with local food. Cassava is considered suitable to substitute the wheat flour's role regarded to its availability, consumption level, and potency as flour [9].

Basically, fortifying food with iron is challenging, because some iron fortificants tend to produce undesirable sensory changes [7]. Unlike iron fortification, sensory changes due to zinc fortification do not appear as a major concern [10]. To reduce

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unacceptable sensory changes on food fortified by iron fortification, NaFe EDTA is suitable to be used, especially for flours [11]. NaFe EDTA also indicates 2-4 times better absorption than ferrous sulphate ($FeSO_4$) in high phytate food including cassava [12], not oxidizing fat or precipitate peptides, and is stable at least for 12 months [13].

One of the important aspects on food fortification is the safety and the acceptance of the product by consumers. The objective of this research is to evaluate the sensory attributes, organoleptic characteristics, to determine zinc and iron content of cassava flour chips fortified by $ZnSO_4$ and NaFe EDTA, and thereby, help to develop a palatable, safe, and nutritionally important food to overcome iron and zinc deficiency.

2. Materials and Methods

Cassava flour was bought in supermarket in Yogyakarta, Indonesia. We used two kinds of fortificants, namely NaFeEDTA as iron fortificant and $ZnSO_4$ as zinc fortificant. The preparation of NaFe EDTA followed the method of Layrisse and Martinez-Torres [14], while $ZnSO_4$ was bought from Merck® (Darmstat, Germany).

2.1 Preparation of Chips

There had been a preliminary experiment to determine the best composition of flour that would be used to make chips with the best sensory characteristic. The results of flour compositions are listed in Table 1.

Table 1 The ingredients of the chips.

Ingredient	Chips	Amount
Cassava flour	K_1	-
	K_2, K_3, K_4	500 g
Wheat flour	K_1	800 g
	K_2, K_3, K_4	300 g
Corn starch	All chips	200 g
$ZnSO_4$	K_1, K_2	-
	K_3	30 mg
	K_4	50 mg
NaFe EDTA	K_1, K_2	-
	K_3	30 mg
	K_4	50 mg

K_1: nonfortified wheat flour chips;
K_2: nonfortified cassava flour chips;
K_3: cassava flour chips fortified by 30 ppm of each $ZnSO_4$ and NaFe EDTA;
K_4: cassava flour chips fortified by 50 ppm of each $ZnSO_4$ and NaFe EDTA.

Chips were made from dough obtained from ingredients listed in Table 1, added by the other additional ingredients such as garlic, salt, butter, parsley leaves, water, and coriander in the same amount for four kinds of chips. The chips were made according to the method reported in Sutomo [15]. Below is the detail procedure for preparation of chips:

Each ingredient was weighed as necessary (Table 1);

Flours were mixed with fortificants for 5-7 min;

The mixture of flour and fortificants was added with grounded garlic and coriander, chopped parsley, and salt;

Water was poured into the flour to make dough;

Dough was flattened to about 1 mm thickness by doughroller;

The flattened dough was cut to small square shape;

The square shape dough then was fried in hot cooking oil until it turned to yellow-brownish chips.

2.2 Fortification

The fortificants were added to the flour in the early step of dough preparation. The dose levels of fortificants were based on minimum level of zinc and iron premix of flour fortification suggested by Indonesian government. The doses used were 0 ppm (non fortification), 30 ppm of each fortificant (30 mg of each fortificants/1,000 g flour) and 50 ppm of each fortificant (50 mg of each fortificants/1,000 g flour).

2.3 Sensory and Organoleptic Test

Sensory attributes consisting of color, taste, flavor, and texture were analyzed subjectively by researcher. Organoleptic characteristic (preference) was evaluated by 25 semi-skilled panelists using hedonic scale method. The method used six preference scale: 6 =

like very much; 5 = like moderately; 4 = like slightly; 3 = dislike slightly; 2= dislike moderately; 1 = dislike very much. Twenty five panelists were students of Scholl of Health Nutrition, Faculty of Medicine, Universitas Gadjah Mada, Indonesia who ever did the similar test before. Four samples were evaluated in the same time, and panelists rinsed their mouth using water between samples.

2.4 Determination of Zinc and Iron Contents

Zinc and iron contents were measured using Atomic Absorption Spectrophotometry.

2.5 Data Analysis

Sensory test data were explained descriptively. Chips preference data were analyzed statistically by Kendall's W test continued by Wilcoxon test, if there had any significant difference among samples. Zinc and iron content data were analyzed by ANOVA continued by post hoc test if there had any significant difference among samples.

3. Results

3.1 Sensory Characteristic of Chips

There was no effect of increasing doses of fortificants on the sensory attributes of the chips. These could be inferred from same characteristics of K_2, K_3, K_4 in Table 2. However, there was difference between wheat flour chips (K_1) and cassava flour chips (K_2, K_3, K_4). Even, the difference could be noticed in the dough making process. Unlike wheat flour dough, the cassava flour dough was not elastic and quickly be dry.

3.2 Preference Difference of Chips

Two statistical analyses were done in this study. The first analysis used four samples (K_1, K_2, K_3 and K_4) with K_1 as control. The second analysis used 3 samples (K_2, K_3 and K_4) with K_2 as control. The results of first statistical analysis were listed in Table 3. It can be inferred that there was significant difference of panelist preference among samples in color, flavor, and taste attribute. Comparisons of mean value in each attribute shows that K_1 chips' mean value was the highest among the samples. This means that color, flavor, and taste of K_1 were mostly liked by the panelists. While, the preference to texture attribute tend similar in all samples ($P = 0.061$).

Table 3 also showed the second statistical analysis. Flavor, taste, and texture of three samples did not differ significantly ($P > 0.05$). This means that dose level of fortificants did not affect the panelist preference on those three sensory attributes. Meanwhile, there were significant differences of panelist preference on chips color, where K_3 chips color was mostly liked. It was shown from its highest mean score in preference test compared with the other chips. The panelists also scored the chips from its overall characteristic. K_1 chip was mostly preferred on its overall characteristic.

3.3 Zinc and Iron Content

Zinc and iron content was declined between K_1 and K_2, but there was increment of zinc and iron contents from K_2 to K_4. More fortificants added would increase zinc and iron contents in cassava flour chips (Table 4). As much 50 ppm iron fortificants added, it will increase the iron content in cassava flour chips to 70.027 ± 0.802 ppm, while the cassava flour contains 40.655 ± 0.802 ppm.

4. Discussion

4.1 Sensory Characteristic of Chips

Fortificants of NaFe EDTA and $ZnSO_4$ added to flour did not affect the sensory characteristic of chips. This report was in agreement with that reported by Hurrel [11] stating that NaFe EDTA was suitable fortificant for flour to minimize undesirable sensory changes. Meanwhile, there were a few studies about the effect of zinc fortification on sensory changes of

Table 2 Sensory characteristics analyze result.

Characteristics	Samples of chips			
	K_1	K_2	K_3	K_4
Color	Bright yellow	Slightly dark brown	Slightly dark brown	Slightly dark brown
Flavor	Tasty	Tasty, musty taste (characteristic of cassava flour)	Tasty, musty taste (characteristic of cassava flour)	Tasty, musty taste (characteristic of cassava flour)
Texture	Crispy and crunchy	Slightly crispy (crumbly), oily	Slightly crispy (crumbly), oily	Slightly crispy (crumbly), oily
Taste	Slightly plain	Tasty, there was after-taste sensation	Tasty, there was after-taste sensation	Tasty, there was after-taste sensation

K_1: nonfortified wheat flour chips;
K_2: nonfortified cassava flour chips;
K_3: cassava flour chips fortified by 30 ppm of each $ZnSO_4$ and NaFe EDTA;
K_4: cassava flour chips fortified by 50 ppm of each $ZnSO_4$ and NaFe EDTA.

Table 3 Results of panelists preference statistical analysis using K1 as control.

Variables	Mean				P of Kendall's W test*	P of Kendall's W test#
	K_1	K_2	K_3	K_4		
Color	5.36^{a}	2.72^{b1}	3.48^{c2}	$3.16^{b,c,d,1,2}$	0.000	0.030
Flavor	4.68^{a}	3.40^{b}	$3.88^{b,c}$	$3.88^{b,c,d}$	0.000	0.125
Taste	4.32^{a}	3.08^{b}	$3.12^{b,c}$	$3.28^{b,c,d}$	0.014	0.759
Texture	4.68	3.96	4.32	3.96	0.061	0.125

*results of panelists preference statistical analysis using K_1 as control;
#results of panelists preference statistical analysis using K_2 as control;
a,b,c,d,1,2 mean scores in rows with the same superscript notation letters are not significantly different ($P > 0.05$);
K_1: nonfortified wheat flour chips;
K_2: nonfortified cassava flour chips;
K_3: cassava flour chips fortified by 30 ppm of each $ZnSO_4$ and NaFe EDTA;
K_4: cassava flour chips fortified by 50 ppm of each $ZnSO_4$ and NaFe EDTA.

Table 4 Iron and zinc content of the chips.

Samples	Fe content (ppm)	Zinc content (ppm)
K_1	45.479 ± 0.801	13.791 ± 0.016
K_2	40.655 ± 0.802	10.057 ± 0.199
K_3	55.234 ± 0.526	17.973 ± 0.120
K_4	70.027 ± 0.802	22.146 ± 0.482

K_1: nonfortified wheat flour chips;
K_2: nonfortified cassava flour chips;
K_3: cassava flour chips fortified by 30 ppm of each $ZnSO_4$ and NaFe EDTA;
K_4: cassava flour chips fortified by 50 ppm of each $ZnSO_4$ and NaFe EDTA;
a,b,c,d mean scores in rows with the same superscript letters are not significantly different ($P > 0.05$).

fortified food [7]. However, since all of zinc fortificants are white or colorless [7], besides, sensory changes due to zinc fortification do not become major problem [16].

As mentioned before, the differences were observed between chips made from wheat flour (K_1) and other chips made from cassava flour (K_2, K_3, K_4). The wheat flour dough was more elastic because wheat flour contains more gluten than cassava flour does. Gluten is a kind of protein which will form a visco elastic linkage if it mixes with water. Cassava flour substitution will decrease protein contents [17, 18] and it will decrease the dough ability in making that viscoelastic linkage.

Cassava flour chip had a darker color than wheat flour chips did (Fig. 1). Color of chips can be influenced by the color of flour itself. Wheat flour is whiter than cassava flour. Cassava flour used in this study has dark yellow color. The color of cassava flour is affected by cassava variety itself and polyphenolase enzyme activity [19]. There would be a bluish-brown color appearing in cassava which is resulted formoxidation by polyphenolase enzyme. Winarno [20] also reported that color of cassava flour is influenced by Maillard reaction. Maillard reaction is browning process resulted from reducing sugar and primary amina group interaction. This reaction is more lasted in traditional process of cassava flour making which uses sunlight to dry the cassava.

The darker color appearing in cassava flour chips is not only caused by the natural color of the composing flour but also caused by caramelization occurred during the frying. Caramelization is a heating process of sugar

Fig. 1 Non-fortified Chips.
K_1 = unfortified wheat flour chips; K_2 = unfortified cassava flour chips.

Fig. 2 Fortified chips.
K_3 = cassava flour chips fortified by 30 ppm of each $ZnSO_4$ and NaFe EDTA; K_4 = cassava flour chips fortified by 50 ppm of each $ZnSO_4$ and NaFeEDTA;
For overal preference chip's properties, of 18 panelist prefer the K_1, 2 panelist K_2, 4 for K_3 and 1 for K_4.

in high temperature resulting brownish compound named melanoidin [21]. Caramelization in cassava flour is easier and faster to happen because cassava flour contains simple sugar resulted from fermentation during cassava drying process. The carbohydrate contents of cassava is 86%-88% while wheat flour is 70%-80% [22].

Texture property is influenced by two kinds of starch contained in the flour. Those starches are amylose and amylopectin. High amylose containing food will have hard texture with high density. Meanwhile, high amylopectin containing food will have crumbly texture with low density [23]. Cassava flour contains more amylopectin than amylose [24] so that chips produced have crumbly and slightly crispy texture (determined subjectively by researcher).

Another difference property was that cassava flour chips had oily texture. This is related to water content in flour. During the frying process, there are two processes happened respectively. First process is evaporation of water from the inner part of food into outer environment. Second process is absorption of oil into the food replacing the water loss during the evaporation. More water contained in the food, more oil will be absorbed into the food [25]. Cassava flour has higher water content than wheat flour [24, 26]. This caused why chips produced from cassava flour have oily texture.

4.2 Panelists Preference of Chips

Two statistical analyses were done in this study. First analysis used 4 samples (K_1, K_2, K_3 and K_4) with K_1 as control. This was to evaluate the panelists' preference between chips made from wheat flour and cassava flour. Second analysis used three samples (K_2, K_3 and K_4) with K_2 as control. This was to evaluate the effect of fortificants dose level on panelists' preference of the chips.

Panelists are more preferred to wheat flour chips (K_1) than cassava flour chips (K_2, K_3 and K_4) in color, taste, and flavor properties. It is estimated because wheat flour chips have brighter color and do not have acid taste and flavor such as cassava flour chips do. However, panelists preference to texture property was same in all kinds of chips.

Assessment of foods texture is started when the foods are started to be cracked, chewed, and swallowed. Panelists tended to like crispy chips similar with wheat flour chips. Crumbly and slightly crispy texture of cassava flour chips is little bit improved by corn starch existence. Corn starch is usually added in the cookies dough to create crispy and crunchy texture [15].

Another analysis showed that preference score of taste, flavor and texture properties comparing three samples of chips fortified by different level of fortificants dose (K_2, K_3 and K_4) did not differ significantly. It means that increasing level of fortificants did not affect panelists preference on that three sensory properties. Meanwhile, the texture of chips made from cassava flour fortified by 30 ppm of each NaFe EDTA and $ZnSO_4$ was mostly liked.

The similar colour of fortified cassava flour chip in different dosage (Fig. 2) depends on the fortificant. Compared to other iron fortificant, NaFe EDTA is one of iron fortificant which produces least organoleptic characteristic changes including color changes [27]. Then, related to zinc fortification, previous study [28] resulted that there was no undesirable organoleptics changes noticed in bread fortified by more than 100 mg/kg of zinc. In overall performance, wheat flour chips were mostly liked. It was because the chips had bright color, crispy and crunchy texture, and did not have acid and musty taste.

4.3 Zinc and Iron Content

The highest zinc and iron contents were found in the cassava flour chips fortified by of each NaFe EDTA 50 ppm and $ZnSO_4$ 50 ppm. Besides the fortificants themselves, the ingredients which partly contributed to both mineral content in the chip was wheat flour. Wheat flour used in this research was one of Indonesian manufactured wheat flour that had been fortified by zinc and iron. This was why the zinc and iron content in wheat flour chips was higher than non-fortified cassava flour chip's content (Table 4).

Compared to unfortified cassava flour chip, there should be increment of iron content as much as 3.978 ppm and 6.630 ppm in cassava flour chips fortified by each 30 ppm and 50 ppm of NaFe EDTA respectively. However, based on data in Table 4, the increment of Fe content is 14.579 ppm in cassava flour chips fortified by 30 ppm of NaFe EDTA and 29.372 ppm in cassava flour chips fortified by 50 ppm of NaFe EDTA. This higher incremental is caused by the existence of free Fe, which are not bound with EDTA molecule and counted by AAS.

NaFe EDTA fortificant used in this study was made by the researcher with $FeSO_4$ as iron source. Less properly rinsing with aquabidest and NaOH done in the last stage of it making process caused the presence of free iron molecules of $FeSO_4$ which were not bound with EDTA molecules.

Unlike iron content, the increment of zinc content in fortified cassava flour chips was lesser than expected. According to Rosado [29], the percentage of zinc content ion $ZnSO_4$ was 32%. So, there should be increment of zinc content as much as 9.6 ppm and 16 ppm in cassava flour chips fortified by each 30 ppm and 50 ppm of $ZnSO_4$ respectively. However, based on Table 4, there was only 7.916 ppm and 12.089 ppm of zinc content increment. This lesser content was caused by losing zinc molecules during cooking process.

Data of zinc and iron content of the cassava flour chip can be used to estimate how much portion of chips should be eaten by the target population to prevent zinc and iron deficiency. The permitted intake of EDTA was 2.5 mg EDTA/kg body weight/day [30], whereas recommended iron intake from NaFe EDTA was 0.2 mg/kg body weight/day [31]. School children are one of population group who are commonly affected by zinc and iron deficiency. If it's generally assumed that school children's average weight are 30 kg, so they only could consume maximum NaFe EDTA as much as 6 mg/day.

In 1 kg cassava flour chips fortified by 50 ppm of each NaFe EDTA and $ZnSO_4$ there was about 22 mg zinc and 70 mg iron. That one kilograms chips could be divided into ± 67 portions of chips (@ 15 g. This portion was based on average portion of snacks sold in Indonesian markets). Thus, in 1 portion, chips contains about 0.33 mg zinc and 1.04 mg iron.

Based on National Workshop on Food & Nutrition 1998, daily requirement of zinc and iron for school children was 10 mg. So, by the calculation above, maximum consumption of 10 cassava chips portions/day hopefully could help to prevent the children from zinc and iron deficiency.

However, this fortified cassava flour chips is planned as additional food/snack so it is needed another source food of zinc and iron to meet the requirements. The bioavaibility of Fe from NaFe EDTA is about 51% and Zn from $ZnSO_4$ is about 33% in whole wheat flour in rats [32]. So using that assumption, the consumption of 10 portions of chip will only meet about 50% of requirements. Other zinc and iron food source such as egg, meat, fish, beans and green vegetables should be eaten daily to help meeting the requirements.

Although the fortified cassava flour chip has a worse sensory characteristic compared to wheat flour chips, the fortified cassava flour chip is potential way to prevent nutritional problem such as iron and zinc deficiency. However, there should be improvements in some points to produce better chips. One of problem in the making process of cassava flour chips is that the dough was quickly dry and the dry dough will be difficult to be processed henceforth. It needed a specified machine used to process the dough quickly so it can be fried soon. Flavoring powder such as barbeque flavor, cheese flavor, chili taste, etc. can be added to the chips to reduce the undesirable taste in the chips.

5. Conclusions

There was no significant effect of both $ZnSO_4$ and NaFe EDTA on sensory characteristics of cassava flour chips. There were different levels of preference of each cassava flour groups. There was significant difference of zinc and iron contents in each cassava flour groups. Consequently, it can be a potential way to improve the value of cassava as basic ingredients of chips. Then the effectiveness of these fortified chips to improve the hemoglobin and zinc status of people needs further research.

References

[1] S. Almatsier, The Principles of Nutritional Science, Gramedia Pustaka Utama, Jakarta, 2004. (in Indonesian)

[2] M.A. DeBiasse-Fortin, Mineral and trace elements, in: Nutrition Support Practice, Saunders, Missouri, 2003.

[3] World Health Organization, Worldwide prevalence of anaemia 1993-2005: WHO Global Database on Anaemia, 2006.

[4] Tievrani, Wary anemia [Online], 2011, http://jkt.bbtklppm.or.id. (in Indonesian)

[5] H.T. Le, I.D. Brouwer, J. Burema, K.C. Nguyen, F.J Kok, Efficacy of iron fortification compared to iron supplementation among Vietnamese school children. Nutrition Journal 5 (2006) 32.

[6] V. Reddy, Food fortification for reducing micronutrient deficiencies: Public-private partnership [Online], 2003, http://www.ifm.net/industry/food_fortification.htm.

[7] L. Allen, B. Benoist, O. Dary, R. Hurrel, Guidelines of fortification of food with micronutrient, WHO and FAO, 2006.

[8] R. Simanjuntak, The wheat cultivation in Indonesia as an alternatif in reducing the dependency of wheat flour importing [Online], 2008, http://riduansimanjuntak.multiply.com/. (in Indonesian)

[9] A. Djuwardi, Cassava: Solution for food diversity and dependency, Grasindo, Jakarta, 2006. (in Indonesian)

[10] T. Govindaraj, L. KrishnaRau, J. Prakash, *In vitro* bioavaibility of iron and sensory quality of iron-fortified wheat biscuit, Food and Nutrition Bulletin, 28 (3) (2007) 299-306.

[11] R. Hurrell, The Mineral Fortifications of Food, Leatherhead Publishing, UK, 1999.

[12] R.F. Hurrell, M.B. Reddy, J. Burri, J.D. Cook, An evaluation of EDTA compounds for iron fortification of cereal-based foods, Br. J. Nutr. 84 (2000) 903-910.

[13] P.V. Thuy, J. Berger, Y. Nakanishi, N.C. Khan, S. Lynch, P. Dixon, The use of EDTA-fortified fish sauce is an effective tool for controlling iron deficiency in women of childbearing age in rural Vietnam, J. Nutr. 135 (2005) 2596-2601.

[14] M. Layrisse, C. MartInez-Torres, Fe (lll)-EDTA complex as iron fortification, The American Journal of Clinical Nutrition 30 (1977) 1166-1174.

[15] B. Sutomo, To be successfull in biscuits entrepreneurship, Kriya Pustaka Grup Puspa Warna, Jakarta, 2008. (in Indonesian)

[16] F.M. Clydesdale, Mineral additives, in: J.C. Bauernfeind, P.A. Lachance, C.T. Trumbull (Eds.), Nutrient Addition to Food Nutritional, Technological and Regulatory Aspects, Food Nutr. Press Inc., 1991, pp. 87-107.

[17] M.O. Oluwamukomi, I.B. Oluwalana, O.F. Akinbowale, Physicochemical and sensory properties of wheat-cassava composite biscuit enriched with soy flour, African Journal of Food Science 5 (2) (2011) 50-56.

[18] N.O. Eddy, P.G. Udofia, D. Eyo, Sensory evaluation of wheat/cassava composite bread and effect of label information on acceptance and preference, African Journal of Biotechnology 6 (20) (2007) 2415-2418.

[19] I. Kusumaastuti, The comparison of technique of cassava flour making process, Bachelor Thesis, Universitas Gadjah Mada, Yogyakarta, 2003. (in Indonesian)

[20] F.G. Winarno, Food and nutrition chemistry, Gramedia Pustaka Utama, Jakarta, 2002. (in Indonesian)

[21] F.G. Winarno, S. Fardiaz, Introduction: Food technology

2nd ed., Gramedia, Jakarta, 2002. (in Indonesian)

[22] L.K. Mahan, S. Escott-Stump, Krause's food, nutrition & diet therapy, Saunders, Philadelphia, 2004.

[23] S. Koswara, Technology of starch modification [Online], 2009, http://ebookpangan.com. (in Indonesian)

[24] Z. Nahdlah, The characteristics of cassava flour (Manihotesculenta, Crantz) and modified cassava flour (Modified Cassava Flour/MOCAF) and their application in food product, Bachelor Thesis, Universitas Gadjah Mada Yogyakarta, 2010. (in Indonesian)

[25] B. Jamaluddin, P. Raharjo, Rochmadi, Mathemathical model of heat and mass movement on fruit frying process in anaerob condition, Proceedings on National Seminar of Agricultural Technique, Yogyakarta, 2008, pp. 18-19.

[26] M.K. Mahmud, N.S. Hermana, R.R. Zulianto, I. Apriyantono, Ngadiarti, Hartati, Budi, Bernadus, Tinexcelly, Indonesian food composition table, Elex Media Komputindo, Jakarta, 2009. (in Indonesian)

[27] T.H. Bothwell, Iron fortification with special reference to the role of iron EDTA, Archivos Latino Americano de Nutrition 49 (2) (1999) 23-33.

[28] D. Romaña, K.H. Brown, J.X. Guinard, Sensory trials to assess the acceptability of zinc fortificants added to iron-fortified wheat products, Journal of Food Science 67 (2002) 461-465.

[29] J.L. Rosado, Zinc and copper: Proposed fotification levels and recommended zinc compounds, J. Nutr. 133 (2003) 2985-2989.

[30] T.H. Bothwell, A.P MacPhail, The potential role of NaFe EDTA as an iron fortificant, International Journal of Vitamine and Nutrition Res. Nov. 74 (6) (2004) 421-434.

[31] R. Hurrell, I. Egli, Optimizing the bioavailability of iron compounds for food fortification, Institute of Food Science and Nutrition, Swiss Federal Institute of Technology, Zurich, Switzerland, 2006.

[32] S.Z. Akhtar, Z. Rehman, F.M. Anjum, Z. Ali, A. Nisar, Bioavaibility of iron and zinc fortified whole wheat flour in rats, Pakistan J. Zool 42 (6) (2010) 771-779.