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Microbial Fermentation as Means of Improving Cassava Production in Indonesia

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Additional information is available at the end of the chapter

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Abstract

Cassava is one of the pivotal carbohydrate sources for millions of people in Indonesia. Its production up to 20 million ton a year made this country to become the third most prominent producer of cassava. However, cassava is often considered as food sources for marginal people. The majority of individuals still depend on rice and wheat flour for carbohydrate intake. Unfortunately, the elevating consumption of those sources is an imbalance with its products nationally. Both use of rice product and wheat flour is more than 8.5 kg/capita/year. The critical fact is that Indonesia is one of the biggest countries in rice production globally. However, it is also one of the largest, rice importers. Another hand, the existence of wheat flour is the result of imports from other countries and always increasing every year. The Indonesian government has contributed actively to resuscitate local foods including the cassava. There are numerous strategies that have been applied to substitute the wheat flour, however, the characteristic was always far different from its flour. *Mocaf* is the recent trend for Indonesian food industry. It is free of gluten and can easily substitute with wheat flour to produce several types of wheat-dependent-products.

Keywords: cassava, *mocaf*, free gluten, wheat flour, Indonesia

1. Introduction

Cassava (*Manihot esculenta*) is one of the vital carbohydrate sources for millions of people in Indonesia. Moreover, it is categorized as the sixth most essential food crop regarding annual production globally [1]. This crop species belong to the order of Malpighiales and family of Euphorbiaceae. Based on the study by Gibbons, cassava originated from Amazon region in Brazil and domesticated since more than 5000 years BC [2]. This root species spread to other places between sixteenth and nineteenth centuries by Western people [3].

Indonesia is the third biggest producer of cassava after Nigeria and Thailand, in which the production is up to 23.4 million ton in 2014 [1]. Cassava categorized as a friendly crop, since tolerant to drought, can grow on soil with limited nutrient, and resistant to the pest. However, cassava often considered as inferior food sources for middle- to low-income people. It also belongs to one of marginal food crops which is almost never mentioned in the colonial literature. Moreover, cassava is also considered as a crop which has the low amount of protein, minerals, and vitamin substances. Another limitation is that cassava root has a very short shelf life in fresh form up to 2 days [4], and some eatable parts of cassava contain toxic substances called cyanogenic glycosides including linamarin and lotaustralin. If the fresh form is digested without enough pre-treatment, some people may develop intoxication.

The consumption of cassava in Indonesia is higher in rural areas, especially in Java and Sumatra Island. The majority of individuals still depend on rice and wheat flour for the carbohydrate intake. Unfortunately, the increasing consumption of those sources is an imbalance with its products nationally. Both use of rice and wheat flour is more than 8.5 kg/capita/year. The new fact is that Indonesia is one of the most enormous countries in rice production globally. However, it is also one of the largest rice importers. In addition, the presence of wheat flour in Indonesia is the result of imports and always increasing from year to year (**Figure 2**).

2. The use of cassava

In Indonesia, cassava is used as a food product up to 53% and the rest as animal feed, in food industry, and as sources of bio-ethanol. Cassava roots are consumed variously, mostly as a side-dish or snack. In some areas, cassava roots are consumed as the fresh form, which is directly eaten after boiling or frying. Fried cassava could be served by giving a different type of spices such as cheese, BBQ, seaweed, chilli, and salty taste. In some urban areas, especially in Central Java and the Special Region of Yogyakarta, peeled fresh cassava is used as a raw material of solid fermented cassava called *tape singkong* (**Figure 1b**). In West Java, the solid fermented cassava called *peyeum* (**Figure 1a**). This product is made by unpeel cassava as raw material which make this food is different with *tape singkong*. Those fermented by microbial mixed contain a large number of *Saccharomyces cerevisiae* called *ragi* or *usar*.

In some parts of Java Island, especially in the Special Region of Yogyakarta and Central Java, cassava prepared as a dried form called *gaplek* (**Figure 1c**), a chip of roots which was drawn up by peeled, is sliced then and dried in the sun for up to 3 days. When needed, *gaplek* is pounded into *tiwul*, a small granule made by mixing its flour and water which is quite similar to rice grains in shape and size or *gathot* (**Figure 1e**), a steam of slice *gaplek* with brown sugar and grated coconut. Also, root cassava chip can be converted into cassava flour (*tepung singkong*) (**Figure 1j**) which has a rough texture. Then, it can be used to make several types of snacks such as *timus*, *getuk*, *gemblong*, *keripik/opak* (**Figure 1f, g, h, i**). In advance, cassava roots are extracted to provide starch called tapioca (**Figure 1k**). In short, peeled form is grated and washed with the amount of water using sieves and decantation. In large scale, tapioca is usually dried by using flash driers or wholly automated machine. However, many households

still use the sun as a natural dryer. Tapioca mixed with other flours is used to make some products such as gluten-free bread, flatbread, desserts, binding agent, and thickener. The most popular cassava product is a chip. In short, fresh cassava root is piled up and chipped into the diesel-powered chipping machines, and let it dry by the sun or dry machine. After the moisture content of the dried-chips under 15%, then its chip can be fried or heated in the oven. The use of various types of spices will increase consumer appetite (**Figure 1**).

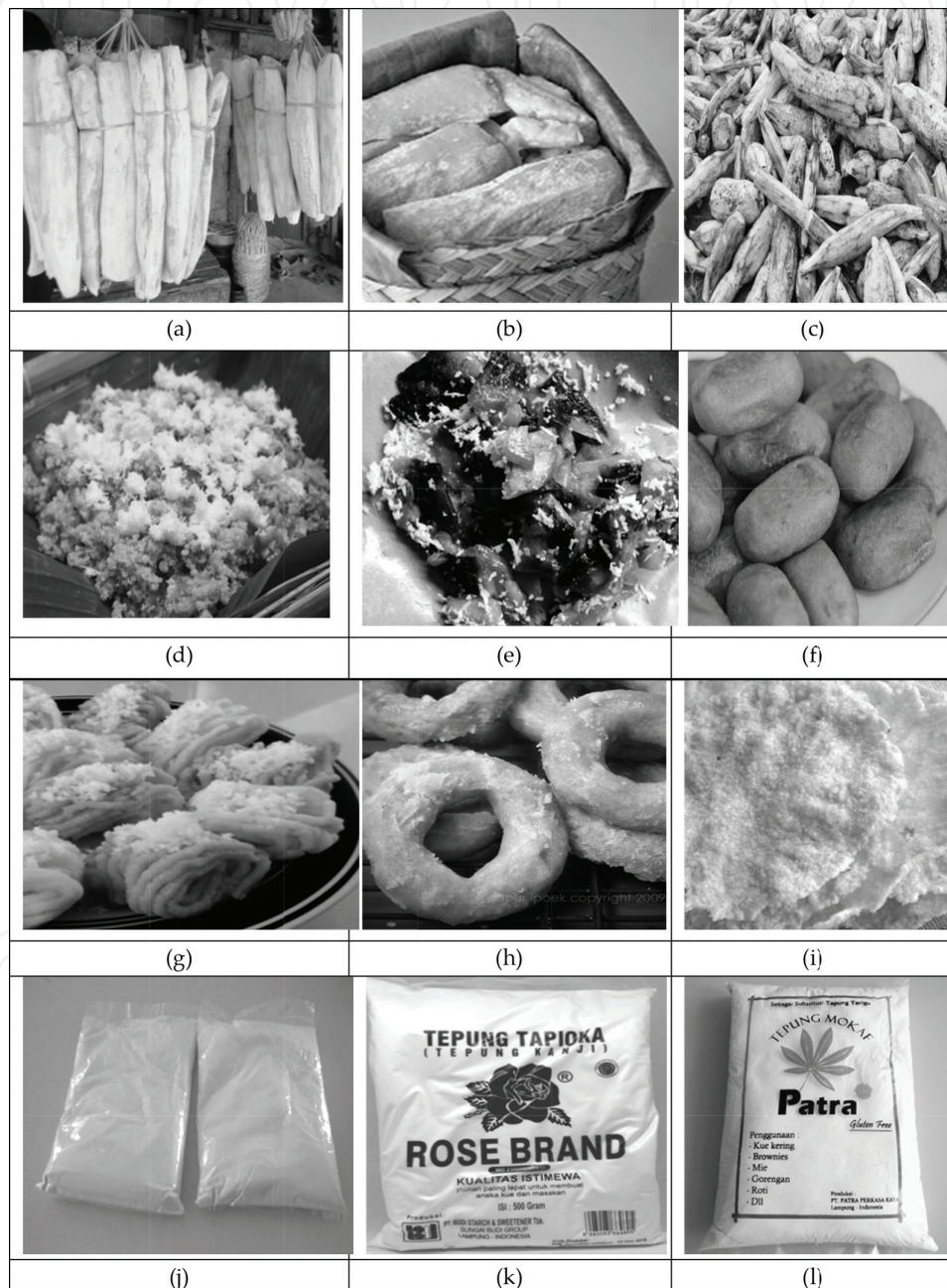


Figure 1. Indonesian cassava-based product available in market: (a) *peyeum*, (b) *tape singkong*, (c) *gaplek*, (d) *tiwul* (e) *gathot*, (f) *timus*, (g) *getuk*, (h) *gemblong*, (i) *opak/keripik singkong*, (j) *tepung singkong/cassava flour*, (k) *tepung tapioca/tapioca*, and (l) *mocaf*. Fermented based products are shown in a, b, and l.

3. Fermented based cassava product: Modified cassava flour (*mocaf*) and its production

Nowadays, cassava roots become one of the trends in Indonesian food industry since its modification form, called *mocaf* (**Figure 1g**), can provide quite a similar characteristic to wheat flour. This fact made the economic value of cassava increasing. The Indonesian government has contributed actively to resuscitate local foods including the cassava. There are numerous strategies that have been applied to substitute the wheat flour; however, the characteristic was always far different from its powder. *Mocaf* is free of gluten and can easily replace with wheat flour to produce several types of wheat-dependent-products. *Mocaf* is a product derived from cassava flour which uses the principle of modifying cassava flour during fermentation. *Mocaf* has better physical characteristic compared to cassava flour on viscosity, gelatinized ability, rehydration capacity, and the solubility. Besides, *mocaf* has a preferable aroma and sensory as resulted from the fermentation. Its native aroma has a cover by the volatile organic compounds such as lactic acid, acetic acid or alcohol. Another advantage is that the product can quickly digest when ingested due to its simple structures that are formed as a result of microbial fermentation. There are numerous ways to produce *mocaf*, however not all methods give similar characteristic. In general, *mocaf* is produced by the step as follows.

3.1. Preparation

Preparation of raw material is one of essential steps in providing excellent quality of *mocaf*. In general, cassava is ready to harvest after 8–12 months after planting. There are two types of cassava: sweet cassava that contains hydrogen cyanide (HCN) content which is less than 40 mg/kg of root cassava and bitter cassava with more than 40 mg/kg of HCN content. HCN is a chemical compound which could release from cyanogenic glycosides from cassava root. The presence of linamarase which present in the cell wall of cassava root will break down the cyanogenic glycosides which placed in vacuoles resulting on releasing acetone cyanohydrin and 2-butanone cyanohydrins, subsequently chemically convert into HCN by alpha hydroxynitrilelyase. Linamarin, a beta-glucosidase, accounts for 95% of total cyanoglycosides and the rest contains lotaustralin [5]. The resulting compound is highly toxic for both animal and human and grouped as the systemic poison. The toxicity is due to the inhibition of cytochrome oxidase together with the presence of a ferric ion in a mitochondrial system. The presence of HCN can affect both acute and chronic onset to human. Moreover, the lack of cobalamin may predispose a human into the higher risk of cyanide-associated neuropathies [6]. World Health Organization recommended that the maximum safe intake of cyanide-containing food for human be 10 mg HCN/kg as described in Codex standard 176-1989 [7], which is much lower than the acceptable limit in Indonesia which is 40 mg HCN/kg [8]. There are several factors that influence the amount of HCN in cassava including harvesting time [9, 10], cultivar [11, 12], and environmental condition [13]. There is much variety of cassava in Indonesia, for low cyanide content including *Krentil*, *Mentega*, *Adira 1*, *Malang 1*, *Malang 2*, *Darul Hidayah*, *Telo Ketan* and *Markonah*. The high content of cyanide is present in *Adira 4*, *Malang 4*, *Malang 6*, *UJ-3*, and *UJ-5*.

3.2. Peeling, washing, chipping, and soaking

The outer layer (skin) cassava was removed using a sharp knife. The peeled cassava is subsequently washed with water until no slime or dirt is found. The resulting violet color after peeling indicates that the cassava contains the amount of cyanide. The peeled cassava is then cut into small round pieces called chip or *sawut* (Javanese language) with the thickness about 0.5 cm. This process could be done using a sharp knife or chipper machine. The process is contributed to the small reduction of cyanide glycoside [14]. The cell wall of cassava root will be damaged and will release endogenous linamarase which is important in converting linamarin from vacuole part into glucose and cyanohydrins [5]. In the last chemical form, HCN will quickly evaporate at 30°C [15]. Additional soaking can be performed before fermentation to reduce the rest of cyanogenic compounds [15–17] (**Figure 2**).

3.3. Fermentation

Peeled cassava roots are soaked in water for 18–72 h with bio-starter. This step is an essential step in producing the excellent quality of *mocaf*. Bio-starter is contained of large number microorganism to accelerate the fermentation process. It can be in liquid or solid form such as powder. The dose for cassava fermentation can be different for various starter products

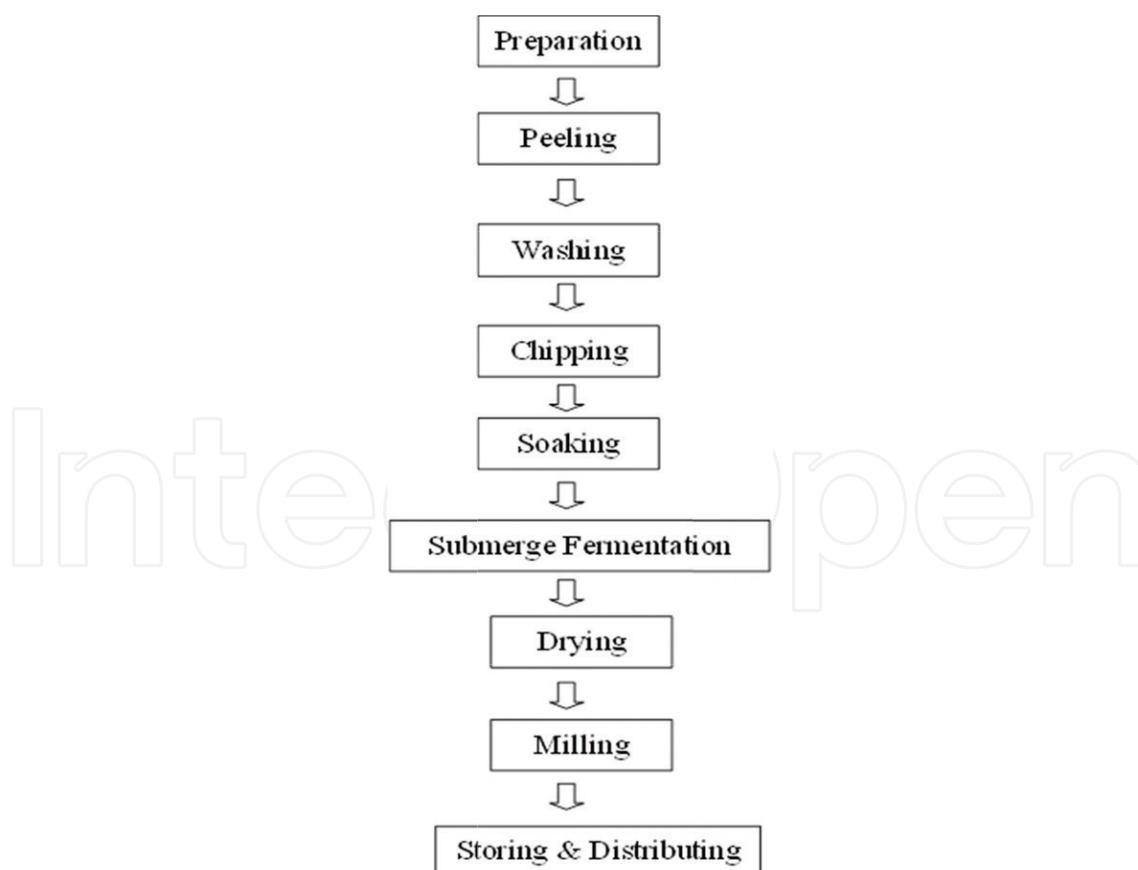


Figure 2. *Mocaf* production step.

in the market. As an example, 1 kg of *Bimo CF* solid starter, and an example of commercial culture starter, can be used for 10 ton of peeled cassava for *mocaf* production. In general, the function of bio-starter is to convert the chemical substance of cassava root during fermentation, which modifies the natural structure, enrich the nutritional value and contribute on other miscellaneous [35]. There are several bio-starters that had been applied to produce good quality of *mocaf*. However, not all of them are sold into the market. The starter can be a single culture, co-culture, and mixed culture. However, spontaneous or natural fermentation not preferably use on large scale of *mocaf* production due to the competitive activities of various micro-flora resulting in unfocus in converting target substance, which is not fit with the requirement of the *mocaf* standard. The repetition of natural fermentation challenging to monitor primarily on a large scale with different batches since the community of microorganism easily changed.

Lactic acid bacteria (LAB) are one of the groups which dominate during natural fermentation of cassava [19–21]. *Lactobacillus plantarum* is one of the LABs which dominated during natural cassava fermentation [19, 20, 22–24]. *L. fermentum* and *L. brevis* are also present during cassava fermentation with the frequency up to 16% [24]. Those bacteria can be potentially used as bio-starter for *mocaf* production. The use of lactic acid bacterial culture starter during cassava fermentation can improve the proximate compositions, fiber content and structure, cyanogenic glycoside reduction, and other miscellaneous properties such as whiteness and viscosity. During fermentation, excreted natural enzymes by that organism will breakdown the cell wall of cassava root and hydrolyze polysaccharide into subtle sugar [28]. Thus, the soluble fiber is elevating while cassava tissue is the breakdown, resulting in soft texture. This process can also improve swelling power and the viscosity of *mocaf* paste [25]. The resulting uncomplex sugar is subsequently converted into another volatile organic substance, which can cover the native aroma of cassava [26]. There are several enzymes which involve in cell wall breakdown including cellulose, hemi-cellulose, amylase, and pectinase. Previous studies showed that *L. plantarum* has amylolytic activity up to 20 U/ml and cellulolytic activity up to 12 U/ml after 18 h of fermentation at a steady temperature of 37°C during cassava fermentation [27]. Enzyme amylase activity from *L. plantarum* also has been observed by several researchers [29–31]. Cellulolytic property of microorganism is essential for breaking down the cell wall of cassava roots, resulting in improving physical properties of a *mocaf* product. Also, the presence of amylase is vital on hydrolyzing starchy substances into subtle sugar. That sugar is necessary for cell growth of bacterial culture. On the other hand, the rest of sugar will be converted into the trace of volatile fatty acids (acetic, propionate, and butyrate) and alcohol by other indigenous activities that happen on the last fermentation to cover unpreferable cassava sensory and aroma [30].

Another advantage of using bio-starter containing LAB is that *L. plantarum* could eliminate the cyanogenic glycoside up to 80% during single fermentation [18, 30, 32–34]. So, the addition of exogenous linamarase during fermentation could be excluded. Gunawan et al. also reported that the use of *L. plantarum* could significantly increase the protein content of *mocaf* products. The presence of carbon and nitrogen will use on developing protein during fermentation. *L. plantarum* improved protein considerably, and cyanide acid content during

cassava fermentation compared to another type of microorganisms such as *Saccharomyces cerevisiae* and *Rhizopus oryzae* [34]. The use of glucose and cellobiose as additional nutrients during fermentation by *L. plantarum* also could increase the activity of linamarase and amylase [30]. The temperature setting and salinity also have a significant effect on survival rate

Criteria	Requirement
Morphology	
Form	Fine particles
Smell	Normal
Color	White
Foreign bodies	Not detected
Insects and their stadia	Not detected
Fineness	
Passes sieve 100 mesh	Min 90%
Passes sieve 80 mesh	100%
Moisture	Max 13%
Ash	Max 1.5%
Crude fiber	Max 2%
Degree of whiteness (MgO = 100)	Min 87
Sulfur dioxide (SO ₂)	Negative
Acid degree (ml NaOH 1 N/100 g)	Max 4
HCN (mg/kg)	Max 10
Metal contamination (mg/kg)	
Cadmium (Cd)	Max 0.2
Lead (Pb)	Max 0.3
Tin (Sn)	Max 40
Mercury (Hg)	Max 0.05
Arsenic (AS)	Max 0.5
Microbial contamination (colony/g)	
Total plate count (35°C, 48 h)	Max 10 ⁶
<i>Escherichia coli</i>	Max 10
<i>Bacillus cereus</i>	Max 10 ⁴
Fungi	Max 10 ⁶

Table 1. The Indonesian national standard for *mocaf*.

and either acetic or lactic acid production during fermentation [27]. The use of single starter does not mean that one microorganism does the whole fermentation process. The addition of only culture starters such as *L. plantarum* inhibited the natural development of heterolactic microorganism. Kresnowati et al. reported that the combination between *L. plantarum* and *Bacillus subtilis*, *L. plantarum* and *Aspergillus oryzae*, *B. subtilis* and *A. oryzae* as co-culture starter improved *mocaf* production [36]. The presence of *A. oryzae* elevated the protein content. The proximity of *L. plantarum* and *B. subtilis* on co-culture fermentation gives a better effect on reduction of cyanogenic glycosides and sugar hydrolysis. Verachtert et al. explained that the use of mixed culture could elevate the growth rate, improved biotransformation, and higher yield in the products [37]. The successful stories of diverse culture are on *tempeh* fermentation [38], beer production [37], and wine production [38–40]. The commercial culture starter for *mocaf* output in Indonesia called *Bimo CF*, a biologically modified cassava flour, used a different type of lactic acid bacteria as the mixed-culture starter. The application of *Bimo CF* is conducted in several studies [41, 42]. An experiment using beta-carotene-producer - cassava cultivar called *Adira 1* using *Bimo CF* as a culture starter has been conducted in small scale [43].

3.4. Drying, milling, storing

After fermentation, chips were dehydrated using drying machine or sun drying for maximum 1 day. It depends on the heat transfer in relation with water evaporation on the surface area of chips. Low moisture content (less than 13%) of chips can store into a plastic bag for the long-term storage. So it cannot quickly absorb the water from outside. Dried fermented chip was then milled to produce a grayish-white flour and then was sieved by 80 mesh and 100 mesh filter to achieve the standard size of commercial flour as setup by Indonesian government authorities. *Mocaf* also can be stored using a transparent plastic bag to barrier the product from the air, water or animal such as bugs.

3.5. Quality control

To evaluate the quality of the output and to protect the people, Indonesian authority called *Badan Standardisasi Nasional*, the Republic of Indonesia has setup *mocaf* standard for commercial use as mentioned in *Standard Nasional Indonesia* (SNI) 7622: 2011. The details of information are projected in **Table 1**.

4. The use of *mocaf* as wheat flour replacement and its implication

Currently, Indonesia is facing the limitation of wheat flour, which is the primary alternative to other staple foods including rice and corn. Moreover, it has been categorized as the essential core of food stabilization program that has been setup by Indonesian government since a long time ago. But, wheat flour is also one of the national burdens, since the plant itself cannot grow well in this land. It has been imported since the 1950s, and the number of import is

increasing dramatically every year [44]. Wheat flour is the primary material for most of the Indonesian food products, such as noodle, bread, biscuits, cake, various fried-food products called *gorengan*, etc. In the past, the use of wheat flour was likely only distributed to the rural area, but from time to time, it has also been spread to the urban area. The presence of wheat in the Indonesian market is mostly an import from Australia. It accounts about 65% of the total wheat import, followed by Canada, India, and United States. Australian wheat meets the requirement of noodle industry in Indonesia. The Australian wheat shows proper milling extraction, less foreign material, and low moisture. The resulting flour produces bright noodle color and consistent dough properties. Moreover, those are cheaper, and the country is relatively close to Indonesia, so the shipping is much easier [45]. Based on the data in 2015, wheat in Indonesia is mostly used as noodle materials. It calculates about 58% which consists of 18% of the wet noodle, 36% for instant noodle, and 4% of dried noodle. The rest is used as bread (16%) and biscuit (26%) materials [46]. Instant noodle is the dominant choice for Indonesian people who do not have enough time to cook. Its price is also cheaper than rice. Bread and biscuits are likely used as an alternative to breakfast option especially for urban people.

As mentioned earlier, the characteristic of *mocaf* is relatively same as wheat flour. In comparison to native cassava flour, *mocaf* shows better aroma, flavor, and other physical and chemical properties. The characteristic of cassava flour improved during microbial fermentation and additional physical treatment. On the other hand, *mocaf* shows lower price when compared to wheat flour and is safe to people who have gluten intolerance and gluten allergy. These are the first onset on developing the autoimmune disorder called celiac disease. Furthermore, the presence of gluten for people who had celiac disease can destroy their villi of the digestive tract. This protein is found in several grains such as wheat, rye, and barley. The absence of gluten in *mocaf* could be used for health campaign to attract people in replacing wheat flour to *mocaf*. Also, *mocaf* easily digests in the body due to the fermentation process. Fresh cassava also rich of hydrocoumarin such as scopoletin and scopolin which have pharmacological activities such as anti-cancer, anti-inflammatory, anticoagulant, and anti-microbial [47]. However, the study about the presence and its effect on these secondary metabolites in *mocaf* has never been conducted. So, *mocaf* provides healthier impact in people, and this can be the primary advantage to compete with the wheat flour.

As *mocaf* has similar characteristic to wheat flour, it can be used as important materials for making noodle including instant noodle [48, 49], bread [50–53], and other products [54]. One of commercial *mocaf*-based instant noodle called *Mie Ayo*, has successfully launched in the public market (**Figure 3**). This product development involves university, government institution, and micro, a small and medium enterprise called *Putri 21*. *Mocaf* is a potential source for Indonesian industry to diver and replace the use of wheat flour in the future. The availability of *mocaf* in the market could pull down the dependency of wheat flour time to time. To substitute or even replace wheat flour with *mocaf*, the Indonesian government encourages people to use local materials including cassava for *mocaf* production. The government launched commercially *mocaf* standard SNI 7622 in 2011. There are several funding sources from the government to the



Figure 3. *Mie Ayo*, one of *moca*-based noodle product in the market.

institution that actively involved in public service, especially in giving knowledge to people to build community capacity on *moca* development. The funding by Indonesian government is variety including *moca* production, *moca* usage, and the marketing strategies. Java is the most focus island on *moca* development. Several districts have been setup to be a center for *moca* production including Trenggalek, Pacitan, Ponorogo, Blitar, Malang, Tulungagung, and Kediri. Those belong to East Java. However, *moca* also has been developed in Central Java and the Special Region of Yogyakarta. The biggest *moca* mill is in Trenggalek. The production of *moca* on industrial scale also spread to outside Indonesia including Malaysia. That country has factory called Malaysian *Moca*Sdn Bhd which has been operated since 2015 [55] (**Figure 3**).

5. Conclusion

Moca transform from cassava flour which is less useful to substitute or even replace the presence of wheat flour. The use of microbial fermentation and additional physical treatment can develop new transform product, one step after cassava flour, called *moca*. This powder is a new hope for Indonesian people to reduce wheat grain import that has been conducted since the 1950s and dramatically increased from time to time. Because the wheat plant itself difficult to grow in every part of Indonesia. On the contrary, wheat-based food product seems gradually stapled in replacing rice, corn, and cassava mainly in the form of noodle and bakery products. *Moca* has similar characteristic to wheat flour. It can be use to substitute or replace the use of wheat flour. However, this can go slowly due to political issue of big industries or the dependency of people to wheat flour as staple product for more than 50 years. Indonesian government encourages people to shift wheat flour with *moca* by giving various funding, education, machine, and workshop to people especially for micro, small and medium enterprises (*Usaha Mikro Kecil Menengah*, UMKM). On the other hand, different types of cassava products still exist and are accepted by people such as *peyeum*, *tape singkong*, *gaplek*, *tiwul*, *cempong*, *gemblong*, *gethuk*, *opak*, etc. Those belonging to food heritage needs to be preserved.

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