



Chemical hazards associated with instant black rice beverage

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Abstract

The primary objective of this study was to analyze some chemical hazards, develop a HACCP plan and its validation to ensure a safety system for production of instant black rice beverage. Chemical hazards in food and beverage produced from cereal are mostly from natural occurrence. Lead and aflatoxins, which could be produced by toxigenic molds associated with black rice and emerged at each stage of the production was described. Knowing of product characterization, raw materials, ingredients, and the production flow diagram are the keys to develop a HACCP plan. This plan was developed the execution of hazard analysis (HA), identifying the critical control points (CCPs), establishment of critical limits (CLs), monitoring procedure, establishment of corrective action, establishment of verification procedure and establishment of record keeping. The validation of HACCP plan was based on the safety hazard testing, scientific publication and the regulatory documents. Status of the control measures and effectiveness to ensure the chemical safety of instant black rice beverage were discussed.

Keywords : *Instant beverage, HACCP plan, chemical hazards, validation, and black rice*

1. Introduction

Safety issues of foods are becoming the hot issues for consumers, since foods could cause undesirable effects on their health. Food borne illness and food toxicity are becoming main scares of consumers' consumption around the world. European food fears have been rooted in the UK society for at least 150 years (1). Approximately 16.7% of the population (47.8 million people) was reported to have been affected by food related illnesses in America in 2011 (2). Similarly, Saltini and

Akkerman (3) reported that in Europe foodborne illnesses affected about 1% of the population (i.e. several million people) each year. Public health risks and related food crises have both potential direct and indirect impacts on economic issues (damage to reputation and brand names), which can result in considerable losses in market value, and reputation, leading to potential bankruptcy of companies and brand names. Scandals and emergencies related to food safety issues are increasingly becoming issues of fear and obstacles to

food market expansion throughout the world. Safety hazard analyses of raw material and finished products are crucial to ensure the safety of products whereas the hazard analysis critical control points (HACCPs) is also important for the food industry in terms of identification of potential hazard in foods and establishment of the control system to ensure the food safety. It is a preventive system, which takes into consideration the whole chain of food production before the biological, chemical and/or physical hazards affecting the safety of food products. Furthermore, HACCP system is intended to address hazards by elimination or reduction to acceptable levels, which is essential to the production of safe foods (4). HACCP plan is needed to do validation in order to make sure that system could work well or not. Validation is defined by the US National Advisory Committee on Microbiological Criteria for Foods (5) as the element of verification focused on collecting and evaluating scientific and technical information to determine whether the HACCP plan, when properly implemented, will effectively control the hazards. Processing equipment, monitoring devices and electronic record keeping systems can be validated to ensure the system performs accurately and reliably in controlling the hazards (6, 7). There are a number of approaches to validation of control measures including scientific publications, historical knowledge,

regulatory documents, experimental trials, scientific models, operational data, and surveys. However, literature reviews from scientific publications, regulatory documents and experimental trails were used in this study. Therefore, the objective of this study was to analyze chemical hazards, develop a HACCP plan and its validation to ensure a safety system of instant black rice beverage.

2. Materials and methods

2.1 Raw materials

The raw materials used in this study were obtained from the Siam MiraGro Co.,LTD, located in Tambon Bankoh, Mueng Khon Kaen, Thailand 40000. Samples were randomly taken from three lots and sent out to the accredited laboratory to analyze for the safety level of products.

2.2 Instant black rice beverage preparation

Instant black rice beverage was prepared by the pilot scale extraction of rice bran obtained from the milling process and centrifuged to separate the solution and sediments. The extracted solution was dried to be powders using pilot scale drum drying. The powder then was ground, blended with other ingredients, packed into aluminum foils, and tightly sealed. The production flow diagram of instant black rice beverage is presented in figure 1.

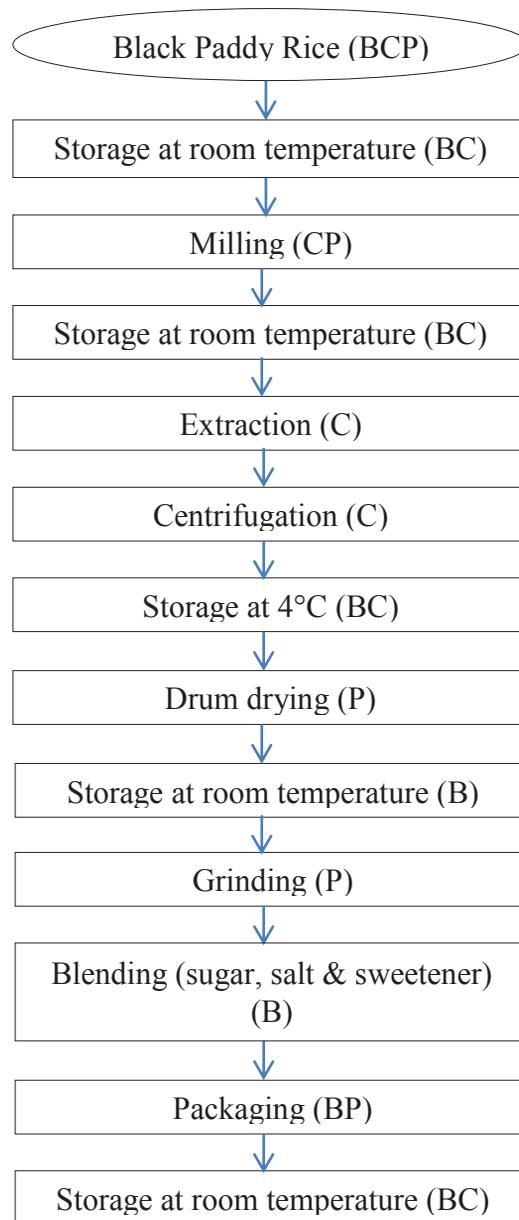


Figure 1. Product flow diagram of instant black rice beverage with safety hazard analyses. B, C and P: biological, chemical and physical hazards, respectively.

2.3 Chemical hazard analysis

Some chemical hazards were analyzed in this study. Heavy metal content (lead) was analyzed using the method of the Association of Official Analytical Chemists (8). The aflatoxin was measured by HPLC analyzer (9).

2.4 HACCP plan

HACCP plan was accompanied to evaluate the safety of the whole process of instant black rice beverage production. The seven principles of HACCP, conducting hazard analysis (HA), identifying the critical control points (CCPs), establishment

of critical limits (CLs), monitoring procedure, establishment of corrective action, establishment of verification procedure and establishment of record keeping were conducted. The decision tree diagram was used to identify potential

hazard at each stage of processing is a CCP or not (see in fig.2). Validation of the HACCP plan was also implemented based on the regulative documents, scientific publication and the result of experiments.

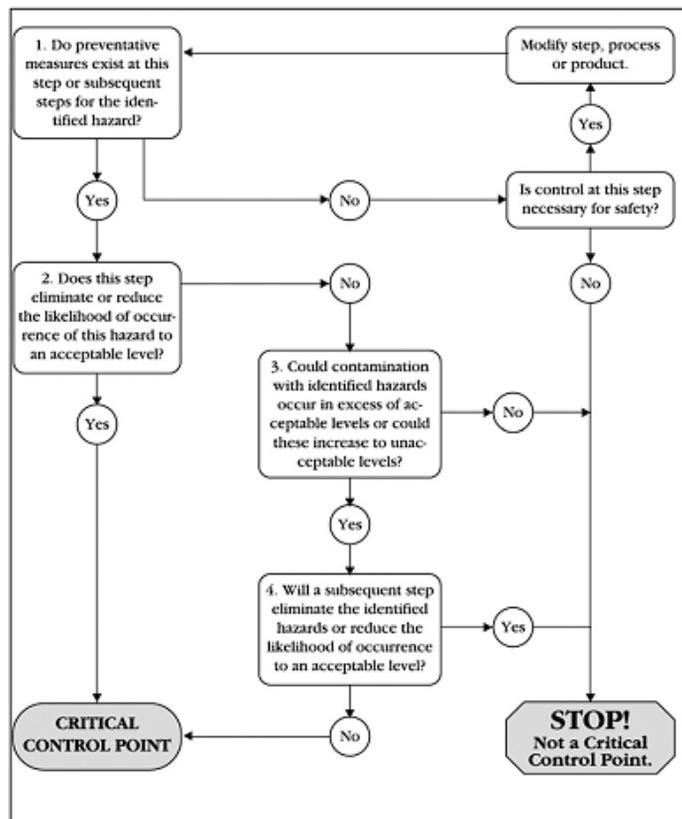


Figure 2. Decision tree diagram for HACCP plan (5)

3. Result and discussion

3.1 Raw material

Table 1. Levels of chemical hazards in paddy rice

Level of safety hazard	I (n=24)	II (n=20)	III (n=20)	Acceptable level
Lead (mg/kg)	0.050	0.023	0.060	≤ 2 mg/kg (FAO/WHO 2002) (10)
Aflatoxin content ($\mu\text{g}/\text{kg}$)				
B ₁	0.52	ND	ND	10-50 $\mu\text{g}/\text{kg}$ USFDA and FAO (11)
B ₂	0.2	ND	ND	
G ₁	ND	ND	ND	
G ₂	ND	ND	ND	
Total aflatoxin	0.72	ND	ND	

Note: data were inspected and certified by the Central Laboratory (Thailand) Co.,Ltd, ND = Not detected

The lead content of lot III was 0.060 mg/kg higher than in lot II and I, which were 0.050 mg/kg and 0.023 mg/kg respectively. Lead associated with black rice could be a result of rice cultivation on the lead contaminated soils because heavy metals are naturally presented in environment by industry and environmental pollutants (12). Different locations resulted in the different lead content presented in paddy rice. FAO/WHO (10) has limited the upper acceptable level of lead as ≤ 2 mg/kg thus paddy rice in each lot was safe from the contamination of lead. The aflatoxin in lot I was detected for aflatoxin type B1 (0.52 $\mu\text{g}/\text{kg}$) and B2 (0.2 $\mu\text{g}/\text{kg}$), while lot II and III were not detected. This study showed that aflatoxin contents of each lot was lower than the

study of Liu, Gao (13) who has reported that the whole rice grain in Liaoning province in China contained total aflatoxin of 3.87 $\mu\text{g}/\text{kg}$ and decreased to be 0.88 $\mu\text{g}/\text{kg}$ by de-husking in brown rice. They have concluded that these grains are safe for human and livestock consumption and for trading and there was no significant difference in whole grain rice and brown rice over a 10-years storage period. On the other hand, the USFDA and FAO adopted the maximum allowable levels of aflatoxin typically ranging from 10 to 50 $\mu\text{g}/\text{kg}$ for all cereal products (11). Therefore, paddy rice used in this study did not pose a big problem with lead and aflatoxin contamination n.

3.2 Instant black rice beverage

Table 2. Levels of chemical hazards in instant black rice beverage

Level of safety hazard	I (n=20)	II (n=20)	III (n=20)	Acceptable level
Lead (mg/kg)	0.038	0.031	0.082	≤ 2 mg/kg (FAO/WHO 2002) (10)
Aflatoxin content (µg/kg)				
B ₁	ND	ND	ND	
B ₂	ND	ND	ND	
G ₁	ND	ND	ND	10-50 µg/kg USFDA and FAO(11)
G ₂	ND	ND	ND	
Total aflatoxin	ND	ND	ND	

Note: data were inspected and certified by the Central Laboratory (Thailand) Co.,Ltd, ND = Not detected

The result of chemical hazards analyses showed that lot III consist lead content (0.082mg/kg) higher than in lot I&II (0.038mg/kg and 0.031mg/kg respectively). The lead contents in paddy rice and instant black rice beverage were at acceptable level. The proliferations of the lead contents maybe a result of the accumulation of lead in rice bran or depends upon the time of sample storage and the type of product (14). Moreover, they could differ according to the location of rice cultivation. Lead (Pd) is a harmful chemical hazard for human health. Consumption of lead associated food is firstly permeated into internal organs and then accumulated in the osseous tissues. The toxic effects of lead include functional disorder of the cardiovascular system, kidneys and nervous system (15). However, the lead content of each lot was lower than acceptable level of FAO/WHO 2002, which stated the acceptable lead contents as ≤ 2 mg/kg (10). It means that instant black rice is safe from lead contamination.

The aflatoxin content in each lot of instant black rice beverage was not detected

in this study. The USFDA and FAO adopted the acceptable level between 10-50 µg/kg for all cereal products(11). However, the aflatoxin could occur by the presence of toxigenic molds during improper storage of raw materials (16). It could also occur even if during storage in refrigerator through improperly packaged foods or even through an open refrigerator door during cargo by poor cleanliness refrigerator seals, or are already growing from lack of proper sanitation or warm temperature. The mold species *Penicillium* and *Cladosporium* are always present in the refrigerator sides and capable to produce poisonous compounds (mycotoxin, aflatoxins) that spread throughout the refrigerated foods and are known to be potent carcinogens(17). However, the mold presented in this study was less than 10 cfu/g (18, 19), resulted in not detected of aflatoxin in finished products (Instant beverages). It was indicated that instant beverage was not posed to chemical hazards either lead or aflatoxin, which is a safe product for consumers' consumption.

3.3 HACCP plan

a/ Product characterization

Table 3. Characterizations of instant black rice beverage

Product Category: Instant black rice beverage	
1. Product Name(s)	Instant black rice beverage
2. How it is to be used	Ready to eat product (RTE product)
3. Type of Packaging	Aluminum foil
4. Length of Shelf Life, at what temperature?	Two years, keep it at room temperature
5. Where it will be sold?	Retailers, consumer, hotels, food service
6. Labelling instructions	Expiry date
7. Special distribution control	Distribute at room temperature

b/ List of raw materials and ingredients

Table 4. List of raw materials and ingredients used for instant black rice beverage production

Raw material/ Ingredients	Appearance	Storage	Packaging	Volume	Others
Tap water	Liquid and portable	Pipe system	-	-	City supplies
Rice bran	Dried powder	Refrigerator	Plastic bag	10 kg	Company
Sugar	Crystalized powder	Room temperature	Plastic bag	1 kg	Company
Salt	Crystalized powder	Room temperature	Plastic bag	1 kg	Company
Sweetener	powder	Room temperature	Plastic bag	1 kg	Company
Packaging	Aluminum foil	Room temperature	Roll covered by plastic	25 kg	Company

c/ HACCP plan for instant black rice beverage production

Table 5. HACCP plan for instant black rice beverage production

CCPs	Hazard description and HACCP plan					
	Hazard description	Critical limits	Monitoring	Corrective actions	Verification	HACCP records
CCP1-C1	Naturally contaminated with heavy metal and aflatoxin	Lead ≤ 2 mg/kg Aflatoxin = 10-50 µg/kg	Sampling and analyze for the safety hazard level	Reject the sample if safety hazard levels are exceed the acceptable level	Result of safety hazard analysis must be reported to QA manager	Lab results
CCP2-C1	Aflatoxin presented with mold growth	Aflatoxin = 10-50 µg/kg	Keep rice bran with low moisture <13% and in cold temperature 5 ^o -10 ^o C) Mold and Aflatoxin testing	Monthly check moisture and temperature of storage room Immediately process rice bran or drying rice bran to <13% moisture	Report test result to QA manager FIFO system	Test result Lot information
CCP3-P1	System not effectively detected metal	-	Equip metal detector GMP program	Damages of packaging machine or properties must be reported to QA manager	Metal detector Checking GMP practice	Maintenance records Property loss report
CCP4-C1	Aflatoxin produced by mold	10-50 µg/kg	Sampling & safety hazard analyses of finished products	Modify previous stage	Recheck raw materials and other storage stages	Lab result

3.4 Validation of HACCP plan

Four critical control points were found as the main points associated with chemical hazards in the production of instant black rice beverage. These CCPs were validated according to the testing result of this research comparing with the regulatory documents and the results of previous studies as listed below:

CCP1-C1: Receiving of raw materials. This stage was validated base on the test result of paddy rice as presented in table 1 and regulative documents. The lead content of each lot was less than the maximum level (2 mg/kg) of the regulatory of FAO/WHO (2002) (10). Meanwhile, the aflatoxin content of each lot was also less than maximum level of USFDA (United

States Food and Drug Administration) and FAO, which adopted the maximum allowable levels of aflatoxin ranges typically from 10-50 µg/kg for all cereal products (11).

CCP2-C1: Storage stage of rice bran, it was validated according to the testing result of the finished products compared to the previous studies. Mold growth in rice bran can cause instant beverage with high aflatoxin content. Aflatoxin has been shown to be presented in rice bran dependent on geographic locations, growing season conditions and past history of rice. Other management controls may include supplier guarantees. The study showed that mold content in each lot was less than 10cfu/g (18, 19) indicated no aflatoxin, however validation was done by aflatoxin analysis.

CCP3-P1: Packaging of finished products was not validated because this study was not focused on the physical hazard analysis. However, the equipping of metal detector on the packaging machine can protect this stage. Moreover, GMP and maintenance program of the packaging machine could also protect the metal to pass through or directly exist in finished products.

CCP4-C1: Storage of finished product was validated according to the testing result and the regulatory documents (table 2). Lead contents of finished products were also lower than acceptable level of FAO/WHO (2002) as in raw materials. Meanwhile, the aflatoxin content was not detected in the finished products, while the indicator for aflatoxin, mold presented in finished product was less than 10 cfu/g.

4. Conclusion

Based on the chemical hazard analyses of finished products, it is concluded that instant beverage was a safe product for consumers' consumption. The contents of lead and aflatoxin in the finished products of each lot was in the acceptable level, which is prescribed by the regulatory documents of FAO/WHO (<2 mg/kg) and USFDA/FAO (10-50 µg/kg). Knowing of product characterizations, raw materials, ingredients, and the production flow diagram are the keys for effective implementation of HACCP plan. It is also important to conduct hazard analysis (HA), identify the critical control points (CCPs), establish critical limits (CLs), monitoring procedure, establish corrective action, establish verification procedure and establish record keeping. HACCP plan was effectively implemented in the production of instant black rice beverage. In addition, the validation of HACCP was significantly validated, which were based on the safety hazard testing, scientific publication and the regulatory documents. In conclusion, instant black rice beverage is a safe product for consumers' consumption with no association with chemical hazards (lead and aflatoxin). A HACCP plan was effectively implemented and its validation was addressed in ensuring of the safety of products, which is associated with chemical hazards.

5. Acknowledgement

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