Quality Assessment of Physical and Organoleptic Instant Corn Rice on Scale-Up Process

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Abstract. Development of instant corn rice product has been successfully conducted on a laboratory scale. Corn has high carbohydrate content but low in fiber. The addition of fiber in instant corn rice, intended to improve the functioning of the product, and replace fiber loss during the process. Scale up process of instant corn rice required to increase the production capacity. Scale up was the process to get identical output on a larger scale based on predetermined production scale. This study aimed to assess the changes and differences in the quality of instant corn rice during scale up. Instant corn rice scale up was done on production capacity 3 kg, 4 kg and 5 kg. Results showed that scale up of instant corn rice producing products with rehydration ratio ranges between 514% - 570%, the absorption rate ranged between 414% - 470%, swelling rate ranging between 119% - 134%, bulk density ranged from 0.3661 to 0.4745 (g/ml) and porosity ranging between 30-37%. The physical quality of instant corn rice on scale up were stable from the ones at laboratory scale on swelling rate, rehydration ratio, and absorption rate but not stable on bulk density and porosity. Organoleptic qualities were stable at increased scale compared on a laboratory scale. Bulk density was higher than those at laboratory scale, and the porosity was lower than those at laboratory scale.

1. Introduction

Indonesian staple food is rice, corn, sago and tubers. The shift in values, causing other commodities did not have a place as a staple food. So that people's reliance on rice is very high. In order to improve food security to comply the basic food needs, it is necessary to developing alternative staple food products.

Corn is one of the cereals that contain carbohydrates equivalent to rice (72-73%). Corn is generally processed by boiled, baked, or fermented. Corn can be processed into corn rice, as an alternative staple food. Furthermore, corn rice processed into instant products to save time in the presentation. Development of instant corn rice product has been successfully conducted on a laboratory scale [1]. Corn has high carbohydrate content but low in fiber. The addition of fiber in instant corn rice, intended to improve the functioning of the product, and replace fiber loss during the process. The novelty value of this study is the addition of dietary fiber to replace the missing corn fiber during the milling process.

Dietary fiber have many function such as increasing the number of beneficial bacteria in the digestive tract, improving immunity and resistance to pathogenic bacteria, facilitating defecation, and preventing cancer [2]. Fiber loss in corn grains during the process into grits is about 10%, from 2.2% in corn grains to 1.98% in corn grits [1]. Addition of agar fiber at 9.3% during the process of cooking corn rice, produce a product with the fiber content of 2.71% (36.86% increases) [3].

Laboratory scale is the basis of a production process. Scale up process required for industrial- scale production to fulfill consumer needs. Before entering the industrial scale, transition from laboratory scale to pilot plant scale to produce a prototype is needed. Pilot plant stage usually used
to evaluate the idea of developing new products, new food supplies, or different operating conditions. The pilot plant stage is also used to evaluate the development of products, reduce costs, overcome technical problems, and evaluate new product ingredients, process variables, process production, optimization studies, and flavor profile.

Scale up is an activity to get the products that are identical (if possible) on a larger scale than the scale of production that has been previously defined. Product development (source and formulation), the operating unit testing, performance development of the tool, and the critical point determination process is required to be able to scale up. Scale up process requires strength analysis in determining the steps to be taken, including an analysis of operating conditions, design and optimum process [4], and expected to know the condition of the processing for certain, because the adjustment in cooking appliance used on a pilot scale will affect the quality of instant corn rice. Scale up is the increase of production capacity related equipment or technology that is larger than the previous production equipment [5].

Increasing capacity will affect the amount of raw materials, energy, and utilities. However, in scale up process, not necessarily to produce a similar quality to the laboratories scale results [6]. Large-scale processes will not produce a product that is identical to the original product, but will produce a product that resembles the original product. Based on the process and production levels, scale up process that is quite difficult to apply [7]. Therefore, research on scale up production of instant corn rice from lab scale to pilot scale, based on the best treatment baseline laboratories scale research is needed. This study aims to assess the changes and differences in the quality of instant corn rice during scale up.

2. Material and Methods

2.1. Date and place

This research was conducted from April 2011 to September 2011 at the Laboratory of Food Processing, Laboratory Testing of Food and Feed, Centre of Appropriate Technology Development Indonesian Institute of Sciences and Laboratory of Services Analysis, Bogor Agricultural University.

2.2. Materials and tools

The main materials used in this research are hybrid varieties of corn grits P21 obtained from farmers in Bogor, West Java. The fiber material used is agar-agar powder. The support material is sodium citrate. The equipment used in the manufacture of instant corn rice is the sink, soaking tub, chopper, polisher, Aron Tools, steamers, stove, deep freezer, cabinet dryer, sealer, plastic containers for storage.

2.3. Instant Corn Rice Making Process

Corn grits washed and soaked in sodium citrate solution 1% for 2 hours. This soaking process aims to create a more porous structure of the material. The use of sodium citrate solution 1% on corn grits is to produce the fastest rehydration time [8]. Furthermore, corn grits washed and "Aron" processed (boiling corn grits in water at a ratio of 1:4, while stirring continuously) for 25 minutes at a temperature of 85 - 93°C. Aron process aims to pre-gelatinization of starch in corn grits. The volume of water used is one part of corn grits and 4 parts of water [9].

2.4. Experimental design and Statistical analysis

This study design was a single factor, is the process of instant corn rice production on a scale of 3 kg, 4 kg and 5 kg and a capacity of 2 kg (lab scale) as a control. Each treatment was repeated 3 times. Pilot-scale quantities per batch are determined based on the capacity of the available equipment; especially the dryer (cabinet dryer) with a maximum input capacity is 20 kg. Base on a lab scale, from 2 kg of corn grits produce 6.5 kg of corn rice (yield 325%). Corn rice is the input material into the cabinet dryer. The results of the above analysis were compared by a one-way variance analysis (ANOVA). A Duncan’s multiple range test with the option of homogeneous groups (p <0.05), was
carried out to determine significant differences among instant corn rice samples. SPSS 16.00 for Windows was used for this aim.

2.5. Analysis procedures

Samples were analysed physical properties include bulk density [10], porosity [11], rehydration ratio [12], water absorption, swelling rate. The stability of the organoleptic quality of instant corn rice qualitatively was analysed using different test. Organoleptic properties observed are the overall acceptance of the products, using 30 semi-trained panellists.

3. Results and Discussion

3.1. Bulk Density

Bulk density shows the ratio between the weights of a substance to its volume. Bulk density of the product ranged from 0.3661 to 0.4745 (g / ml) (Table 1). The process of scaling up production produce products with significantly different densities, which means that density, was unstable at scale up process.

| Mean of bulk density (gr/ml) | F-Test |
|-------------------------------|--------|
| Upscale                      | Lab Scale (2kg) |
| 3 kg 0.4745                  | 0.3959 | b |
| 4 kg 0.4385                  |        | b |
| 5 kg 0.3661                  |        | b |

A-n: a = not significantly different (p>0.05)
b = significantly different (p < 0.05)

MPanual stirring on aron process causing agar gel is not well mixed, thus causing product sphericity decreases. The empty space between the particles increases causing product density decreases. A high sphericity of kernel causes a neat arrangement and the cavity of kernels getting smaller [13].

3.2. Porosity

Porosity is an important property on instant product. Pores formed during the process will facilitate and accelerate the process of rehydration. Loopholes or pores formed in the instant rice will facilitate the transfer of water and heat during cooking, producing a more tender cooked rice [14].

| Mean of Porosity (%) | F-Test |
|----------------------|--------|
| Upscale              | Lab Scale (2kg) |
| 3 kg 36              |        | b |
| 4 kg 32              | 37     | b |
| 5 kg 30              |        | b |

A-n: a = not significantly different (p>0.05)
b = significantly different (p < 0.05)

The porosity of products ranges between 30-37%, the highest porosity (37%) was resulted from the production capacity of 2 kg (lab Scale) and the lowest porosity (30%) was resulted from the production capacity of 5 kg (Table 2). Different production capacity was resulted products with significantly different porosity, which means that porosity was unstable at scale
up process. Manual stirring on aron process causing adhesion of agar gel on corn rice became uneven; causing porosity of the product is uneven.

3.3. **Rehydration ratio**

Rehydration ratio was the ability of a material to absorb water. Additionally rehydration aims to determine quality (appearance, colour, and aroma) of dry product after absorbing water. Rehydration was strongly influenced by the cell wall elasticity, loss of differential permeability in the membrane of protoplasm, loss of cell turgor pressure, protein denaturation, starch crystallinity and hydrogen bonding macromolecule [15].

| Mean of Rehydration ratio (%) | F-Test |
|------------------------------|--------|
| Upscale                      | Lab Scale (2kg) |
| 3 kg                         | 526 a   |
| 4 kg                         | 514 a   |
| 5 kg                         | 562 a   |

Rehydration ratio of instant corn rice ranged between 514% - 570%, the highest rehydration ratio (570%) was resulted from the production capacity of 2 kg (lab scale) and the lowest rehydration ratio (514%) was resulted from the production capacity of 4 kg (Table 3). Different production capacity was resulted products with not significantly different rehydration ratio, which means that rehydration ratio was stable at scale up process. Rehydration ratio of instant corn rice produced from a variety of production scale was higher than the rehydration ratio of instant porridge fortified with carrot flour (447.96%) [16].

3.4. **Absorption rate**

Absorption rate of instant corn rice ranged between 414% - 470%, the highest rehydration ratio (470%) was resulted from the production capacity of 2 kg (lab scale) and the lowest rehydration ratio (414%) was resulted from the production capacity of 4 kg (Table4). Different production capacity was resulted products with not significantly different absorption rate, which means that absorption rate was stable at scale up process. Absorption rate of instant corn rice produced from a production scale of 2-5 kg was higher than absorption rate of instant corn rice fortified with agar-agar powder and carrot pulp (306%) [3]. High water absorption ensures compactness in food products [17].

| Mean of Absorption rate (%) | F-Test |
|-----------------------------|--------|
| Upscale                     | Lab Scale (2kg) |
| 3 kg                        | 426 a   |
| 4 kg                        | 414 a   |
| 5 kg                        | 462 a   |

Swelling rate of instant corn rice ranged between 119% - 134%, the highest rehydration ratio (134%) was resulted from the production capacity of 3 kg and the lowest rehydration ratio (119%) was resulted from the production capacity of 4 kg. Different production capacity was resulted products with not significantly different swelling rate, which means that swelling rate was stable at scale up process. Swelling rate of instant corn rice produced from a production scale of 2-5 kg was higher than swelling rate of instant corn rice fortified with agar-agar powder and carrot pulp (130%) [3]. High water absorption ensures compactness in food products [17].

3.5. **Swelling rate**

Swelling rate of instant corn rice ranged between 119% - 134%, the highest rehydration ratio (134%) was resulted from the production capacity of 3 kg and the lowest rehydration ratio (119%) was resulted from the production capacity of 4 kg. Different production capacity was resulted products with not significantly different swelling rate, which means that swelling rate was stable at scale up process. Swelling rate of instant corn rice produced from a production scale of 2-5 kg was higher than swelling rate of instant corn rice fortified with agar-agar powder and carrot pulp (130%) [3]. High water absorption ensures compactness in food products [17].
ratio (119%) was resulted from the production capacity of 4 kg (Table 5). Different production capacity was resulted products with not significantly different swelling rate, which means that swelling rate was stable at scale up process. Swelling rate of instant corn rice produced from a production scale of 2-5 kg was higher than swelling rate of instant corn rice fortified with agar-agar powder (9.3%) and fortified with agar-agar powder mixed with carrot pulp (44-119%) [3]. during the process of water absorption, swelling of the particles of rice causing changes in the form of particles of rice [18].

Table 5. Comparison of swelling rate of Instant Corn Rice on Lab Scale to Upscale

|                | Upscale | Lab Scale (2kg) | F-Test |
|----------------|---------|----------------|--------|
| 3 kg           | 134     | 122            | a      |
| 4 kg           | 119     | 122            | a      |
| 5 kg           | 126     |                | a      |

A-n: a = not significantly different (p>0.05)
b = significantly different (p < 0.05)

3.6. Quality stability In Organoleptic

The stability of the organoleptic quality of instant corn rice was done qualitatively using different test. Table 6 show that samples at a capacity of 5 kg, 4 kg, and 3 kg overall quality has no significant difference with control (R). Organoleptic qualities (over all characteristic) of up scaled instant corn rice were stable from the ones at laboratory scale.

Table 6. Comparison of Over All Organoleptic Characteristic of Instant Corn Rice on Lab Scale to Upscale

|                     | Upscale | Control (R) | F-Test |
|---------------------|---------|-------------|--------|
|                     |         | Laboratory Scale (2 kg) | a      |
| 3 kg                |         |              | a      |
| 4 kg                |         |              | a      |
| 5 kg                |         |              | a      |

A-n: a = not significantly different (p>0.05)
b = significantly different (p < 0.05)

4. Conclusion

Scale up of instant corn rice making process producing products with rehydration ratio ranges between 514% - 570%, the absorption rate ranged between 414% - 470%, swelling rate ranging between 119% - 134%, bulk density ranged from 0.3661 to 0.4745 (g/ml) and porosity ranging between 30- 37%. The physical quality of scale up instant corn rice making process were stable from the ones at laboratory scale on swelling rate, rehydration ratio, and absorption rate but not stable on bulk density and porosity. Organoleptic qualities (over all characteristic) of scale up instant corn rice making process were stable from the ones at laboratory scale. The density bulk was higher than those at laboratory scale; meanwhile the porosity was lower than those at laboratory scale.

On increasing the scale of production, it is advisable to make automatic "aron" equipment to obtain optimal results.
Acknowledgment

We would like to thank The Ministry of Research and Technology that has provided research funds and co- researchers, engineers, and analysts who have helped during the research process.

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