Optimization of instant powdered chicken feet broth’s drying temperature and time on pilot plant scale production

N Hidayati and T D Widyaningsih

Department of Agricultural Product Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia

E-mail: tridewantiw@ub.ac.id

Abstract. Chicken feet by-product of chicken industries amounted to approximately 65,894 tons/year commonly used as broths. These by-products are potentially produced into an instant form as an anti-inflammatory functional food on industrial scale. Therefore, it is necessary to optimize the critical parameters of the drying process. The aim of this study was to determine the optimum temperature and time of instant powdered chicken feet broth’s drying on pilot plant scale, to find out product’s comparison of the laboratory and pilot plant scale, and to assess financial feasibility of the business plan. The optimization of pilot plant scale’s research prepared and designed with Response Surface Methodology-Central Composite Design. The optimized factors were powdered broth’s drying temperature (55°C, 60°C, 65°C) and time (10 minutes, 11 minutes, 12 minutes) with the response observed were water and chondroitin sulphate content. The optimum condition obtained was drying process with temperature of 60.85°C for 10.05 minutes resulting in 1.90 ± 0.02% moisture content, 32.48 ± 0.28% protein content, 12.05 ± 0.80% fat content, 28.92 ± 0.09 % ash content, 24.64 ± 0.52% carbohydrate content, 1.26 ± 0.05% glucosamine content, 0.99 ± 0.23% chondroitin sulphate content, 50.87 ± 1.00% solubility, 8.59 ± 0.19% water vapour absorption, 0.37% levels of free fatty acid, 13.66 ± 4.49% peroxide number, lightness of 60.33 ± 1.24, yellowness of 3.83 ± 0.26 and redness of 21.77 ± 0.42. Financial analysis concluded that this business project was feasible to run.

1. Introduction

The high market demand for Broiler chickens in Indonesia yielded by-products of chicken feet as much as 65,894 tons in 2016 [1]. Chicken feet contain glycosaminoglycan, consisting of glucosamine and chondroitin sulfate which are potentially used as an anti-inflammatory agent as an alternative to anti-inflammation of shark fin bones [2]. In addition, chicken feet is rich in calcium, phosphorus and hydroxyapatite and also contain gelatin, chitin/chitosan and collagen that can potentially cure osteoporosis, reduce aging effects, and act as anti-hypertension [3]. Chicken feet are often used as broths. Research on chicken feet seasoning has proven its function as an anti-inflammatory agent, where edema inflammation’s reduction increased from 1st to 5th hours reaching 78.19% with dosage of 200 mg/kg rat body weight [4].

Scaling through the pilot plant is a stage that can provide an approximation of production in industrial scale by identifying critical process conditions, so that the product’s quality can be maintained. The critical condition in the production of instant powdered chicken feet broth is the drying process. The drying temperature and time are critical parameters. The drying temperature and time on pilot plant may be different from the laboratory experiment because the amount of materials...
is multiplied according to the scale-up capacity, different machines and production condition. The aim of this study were to determine the optimum temperature and time of instant powdered chicken feet broth’s drying on pilot plant scale, to find out product’s comparison of the laboratory and pilot plant scale, and to assess financial feasibility of the business plan.

2. Materials and Methods

Materials used in this research were Broiler chicken feet obtained from Hypermart Malang Plaza and industry. Other ingredients used for instant powder on the laboratory scale were dextrin, sugar, garlic, onion and water. While the used on the pilot plant scale were maltodextrin, sugar, salt, garlic granule, shallot granule, fancy onion powder, pepper, chicken fat and water which were obtained from the factory. The materials used for testing were NaOH (Merck), concentrated H2SO4 (Merck), HCl 0.1 N, boric acid, PP indicator, methyl red, Kjeldahl tablet, petroleum ether, glucurunolactone standard (Sigma), sodium tetraborate (Sigma), ethanol absolute, carbazole solution (Sigma), glucosamine kit assay (Megazyme), aquades and ice cubes obtained from CV. Kridatama Persada, CV. Panadia and CV. Makmur Sejati.

2.1. Laboratory scale study

Chicken feet powder was made by pressure cooking method for 1 hour ± 2 minutes and then dried for 12 hours ± 5 minutes in cabinet dryer at 60 ± 5°C. Garlic and onions were also dried for 6 hours ± 5 minutes in cabinet dryer at 60 ± 5°C. Then, the ingredients were mixed according to the percentage of the formulation, the mixture was added by water until it didn’t stick to the bowl. The mixture was dried for 6 hours ± 5 minutes in cabinet dryer at 60 ± 5°C and sieved with 40 mesh screen. The formulation of powdered chicken feet broth is presented in Table 1.

| Material          | Percentage (%) |
|-------------------|----------------|
| Chicken feet powder | 60             |
| Garlic powder     | 10             |
| Onion powder      | 10             |
| Salt              | 18             |
| Dextrin           | 2              |

2.2. Pilot plant scale study

Chicken feet powder was made by autoclaving method for 45 minutes and then cooked by using steam for 45 minutes ± 15 seconds under 1 atm pressure. The drying of chicken feet powder was separated into 2 phases, where the first drying was for 10 hours ± 5 minutes and second drying was for 4 hours ± 5 minutes at 60°C in tray oven. Then, the chicken feet powder was mixed with 20% maltodextrin. The production of instant powdered chicken feet broth every batch was 500 g. Seasoning was added afterwards following this composition: 60% chicken feet powder; 8.5% sugar; 1.5% fancy onion powder; 3.2% garlic granule; 3% of shallot granule and 0.5% pepper then the mixture were crushed together. The mixing process was done by inserting salt into the speed kneader machine and adding 60 ± 5°C water as much as 0.6% of the broth powder’s amount, then it was mixed for 30 seconds. Next, the mixture was added by 60 ± 5°C chicken fat as much as 0.8% and mixed until 90th seconds. After 1 minute 30 seconds, the mixture was added by ingredients that have been previously crushed and the mixing was done up to 4 minutes.

Instant powdered chicken feet broth’s drying process was optimized by using Response Surface Methodology-Central Composite Design. Determination of drying temperature and time based on previous research and through consideration of process conditions at the pilot plant scale. The central composite design for optimization is presented in Table 2. After drying, the powdered broth was sieved with a 10 mesh screen.
Table 2. Pilot plant scale’s research design.

| Std | Run | Factor 1 A: Temperature (°C) | Factor 2 B: Time (minutes) | Response 1 Water content (%) | Response 2 Chondroitin sulfate content (%) |
|-----|-----|-----------------------------|---------------------------|----------------------------|------------------------------------------|
| 1   | 1   | 55.00                       | 10.00                     |                             |                                          |
| 2   | 3   | 65.00                       | 10.00                     |                             |                                          |
| 3   | 9   | 55.00                       | 12.00                     |                             |                                          |
| 4   | 2   | 65.93                       | 12.00                     |                             |                                          |
| 5   | 8   | 52.93                       | 11.00                     |                             |                                          |
| 6   | 4   | 67.07                       | 11.00                     |                             |                                          |
| 7   | 13  | 60.00                       | 9.59                      |                             |                                          |
| 8   | 11  | 60.00                       | 12.41                     |                             |                                          |
| 9   | 7   | 60.00                       | 11.00                     |                             |                                          |
| 10  | 5   | 60.00                       | 11.00                     |                             |                                          |
| 11  | 6   | 60.00                       | 11.00                     |                             |                                          |
| 12  | 10  | 60.00                       | 11.00                     |                             |                                          |
| 13  | 12  | 60.00                       | 11.00                     |                             |                                          |

2.3. Data analysis

The optimization response was analyzed using Response Surface Methodology-Central Composite Design and processed with Design Expert DX 7.1.5. The result of final product analysis was processed using Microsoft Excel, while to compare the characteristics of chicken feet powder produced in laboratory and pilot plant was done by using paired t-test at 5% significance level (Minitab 16.2.1).

3. Results and Discussion

3.1. Characteristics comparison of chicken feet powder on laboratory and pilot plant scale

The results of analysis from chicken feet powder are presented in Table 3.

Table 3. Comparison of chicken feet powder.

| Analysis                        | Pilot Plant Scale       | Laboratory Scale     | Notation |
|--------------------------------|-------------------------|----------------------|----------|
| 1. Yield (%)                   | 18.39 ± 1.57            | 11.37 ± 0.10         | *        |
| 2. Proximate:                  |                         |                      |          |
| - Water content (%)            | 5.43 ± 0.40             | 5.38 ± 0.11          | ns       |
| - Protein content (%)          | 47.47 ± 1.01            | 53.49 ± 1.37         | *        |
| - Fat content (%)              | 15.70 ± 3.05            | 23.89 ± 2.88         | ns       |
| - Ash content (%)              | 10.02 ± 0.11            | 9.32 ± 0.12          | **       |
| - Carbohydrate content(%)      | 21.38 ± 2.18            | 7.92 ± 1.58          |          |
| 3. Glucosamine content (%)     | 5.12                    | 11.53                |          |
| 4. Chondroitin sulfate content (%) | 1.04 ± 0.53            | 2.10                 |          |

Notes:
The amount is an average ± standard deviation of 3 repetitions
ns : no significant difference
* : significant difference (p < 0.05)

The yield on the pilot plant scale was higher than the laboratory scale due to the addition of 20% maltodextrin as filler that can increase the amount of solids of the product. The difference in protein levels due to the autoclaving process that causes lower level of nutrients, including protein [5]. A higher level of ash content on the pilot plant scale caused by chicken’s nails. Autoclaving soften the chicken feet most of the broken main bone were included to be dried and added up the mineral content.

The difference was the addition of 20% maltodextrin. The lower chondroitin content on the pilot plant’s chicken feet powder was related to the characteristics of chondroitin sulphate which is highly
water soluble and unstable to high temperature, while boiling process with high temperature and longer drying time were applied on pilot plant scale.

3.2. Optimization using response surface methodology
Based on the moisture content response’s analysis of variance (ANOVA), it showed that the quadratic model gave a significant effect with p value was 0.0031. While the lack of fit has p value of 0.1549, considered as has no significant effect. The actual equation of the model was as follow:

\[ Y = 27.03273 - 0.57437X_1 - 1.16712X_2 - 0.005X_1X_2 + 0.004895X_1^2 + 0.064875X_2^2 \]

Description: \( X_1 = \) Drying temperature (°C)  
\( X_2 = \) Drying time (minutes)  
\( Y = \) Response of moisture content

Chondroitin sulphate response’s ANOVA showed that linear model gave a significant effect with p value was 0.0040. While the lack of fit has p value of 0.0962, considered no significant effect. The actual equation of the model obtained was as follow:

\[ Y = 3.40860 - 0.020602X_1 - 0.11990X_2 \]

Description: \( Y = \) Response of chondroitin sulphate content

The relationship between the factors to the response was shown in Figure 1.

![Figure 1](image1.png)

**Figure 1.** 3D surface of (a) moisture content and (b) chondroitin sulphate content

Figure 1 (a) shows that only the temperature that has a significant effect on the water content response. The curve shows that the higher the temperature, the lower the water content indicated by the gradation of the colour from green-yellow-dark blue. The ability of the material to release water from its surface increase with the increasing drying temperature and the longer drying process, resulting in a lower moisture/water content [6]. Drying time has no significant effect because the time range used in this study is too narrow. Figure 4.8 (b) shows a decreasing linear shape along with the higher temperature and longer drying time. This is because chondroitin sulphate is a non-heat-resistant compound [7].

The solution obtained by using this method is the optimum point selected by Design Expert 7.1.5’s calculation results are drying process with the temperature of 60.85°C for 10.05 minutes. Verification was done to assess that the optimum response estimated by the program was confirmed by the actual response. The results of the verification are shown in Table 4.
### Table 4. Prediction and verification of instant chicken feet broth on pilot plant.

| Factor              | Temperature (°C) | Time (minutes) | Moisture Content (%) | Chondroitin Sulfate Content (%) |
|---------------------|------------------|----------------|----------------------|---------------------------------|
| Prediction          | 60.85            | 10.05          | 1.97                 | 0.95                            |
| Verification        | 60.85            | 10.05          | 1.90                 | 0.99                            |
| PI low              | 60.85            | 10.05          | 1.73                 | 0.71                            |
| PI high             | 60.85            | 10.05          | 2.22                 | 1.19                            |

3.3. Characteristics comparison of instant powdered chicken feet broth on laboratory and pilot plant

The results of analysis from chicken feet powder are presented in Table 5.

### Table 5. Comparison of instant powdered chicken feet broths.

| Analysis                                      | Pilot Plant Scale (±) | Laboratory Scale (±) | Notation |
|-----------------------------------------------|-----------------------|----------------------|----------|
| 1. Moisture content (%)                       | 1.86 ± 0.04           | 7.04 ± 0.11          | *        |
| 2. Protein content (%)                        | 32.48 ± 0.35          | 33.89 ± 0.78         | ns       |
| 3. Fat content (%)                            | 12.05 ± 0.97          | 10.93 ± 0.87         | *        |
| 4. Ash content (%)                            | 28.92 ± 0.10          | 23.22 ± 0.09         | *        |
| 5. Carbohydrate content (%)                   | 24.64 ± 0.64          | 24.93 ± 1.58         |         |
| 6. Glucosamine content (%)                    | 1.26 ± 0.06           | 1.06 ± 0.77          | ns       |
| 7. Chondroitin sulfate content (%)            | 1.01 ± 0.22           | 0.74 ± 0.02          | ns       |
| 8. Solubility level (%)                       | 50.87 ± 1.23          | 47.08                |         |
| 9. Water vapor absorption (%)                 | 8.59 ± 0.24           | 9.17 ± 0.30          | *        |
| 10. Color                                     | 60.33 ± 1.51          | 59.73 ± 0.75         | ns       |
| - L*                                          | 3.83 ± 0.32           | 5.17 ± 0.25          | ns       |
| - a*                                          | 21.77 ± 0.51          | 25.33 ± 0.23         | *        |
| 11. Free Fatty Acid content (%)               | 0.37                  |                      |         |
| 12. Peroxide number (mek/kg)                  | 13.66 ± 4.49          |                      |         |

**Notes:**

The amount is an average ± standard deviation of 3 repetitions

ns : no significant difference

* : significant difference (p≤0.05)

Differences in moisture content caused by the adding of water until broth mixture didn’t stick to the bowl before it was dried on laboratory scale. In addition, the using of different dryers may also be a factor of the difference in moisture content [8]. Differences in fat content was caused by an addition of 0.8% chicken fat on pilot plant scale to produce a stronger chicken flavor. While the higher ash content on the pilot plant scale can be due to various ingredients added including granule’s form of shallot and garlic. Differences in redness can be due to the addition of filler on the pilot plant’s chicken feet powder that resulting in brighter colour. In addition, shorter powdered broth drying on pilot plant may also affect the differences in redness. The free fatty acid content in this product was 0.37% which is quite high and caused by large oil hydrolysis. While the high peroxide number may be due to the analysis of peroxide and FFA numbers performed more than 1 month after the production. It may also be due to long warming process during chicken feet powder’s drying and a high content of omega-3 and omega-6, (187 mg and 257.1 mg per 100 g chicken feet respectively). Unsaturated fatty acids bind oxygen to their double bonds to form peroxides [9].

3.4. Financial analysis of instant powdered chicken feet broth

The feasibility of a business project based on financial aspects was indicated by the ability of the business to provide financial benefits. The financial analysis is presented in Table 6.
Table 6. Financial analysis of instant powdered chicken feet broth.

| No. | Criteria                  | Value                      |
|-----|---------------------------|----------------------------|
| 1.  | Net Present Value         | Rp. 5,838,964,104.00       |
| 2.  | Internal Rate of Return   | 35.26%                     |
| 3.  | Net Benefit/Cost          | 2.30                       |
| 4.  | BEP cost                  | Rp. 3,873,717,400.00       |
|     | BEP unit                  | 1,076,033                  |
| 5.  | Pay Back Period           | 2 years 9 months 21 days   |

This business project is feasible to run because the value of NPV > 0, IRR value was greater than the prevailing bank interest rate (12%), net B/C ratio was ≥1, PBP was faster than project’s duration (10 years), BEP value was below the number of production value [10, 11].

4. Conclusion

The critical parameters set in the pilot plant are suitable, based on the similarity of characteristics with laboratory scale product. The chosen optimum point of instant powdered chicken feet broth’s drying process is 60.85°C for 10.05 minutes. Financial analysis stated this business project is feasible to run.

References

[1] Directorate General of Livestock 2016 Broiler chicken production according to province
[2] Widyaningsih T D, Hapsari, D, Wijayanti, N, Dita, S, Dhyantari, O, Milala C T 2015 Conf. Proc.of Agroindustry and National Workshop FKPT-TPI, Universitas Brawijaya Malang Indonesia, pp. 5-9
[3] Guimaraes, M, Jose, C, Curvelo, S, Pollana A F 2012 Collagen extraction from chicken feet for jelly production J.Acta Sci. Maringa 34 345-351
[4] Milala C T, 2014 The Influence of Instant Chicken Feet Seasoning as Anti-inflammatory Effect to Male Wistar Rat Induced by Carrageenan Undergraduate Thesis Universitas Brawijaya Malang Indonesia
[5] Sundari, D, Almasyhuri, Lamid, A 2015 The Effect of Cooking Process on Nutrient Composition of Protein Source Food stuff Libangkes Media 25 235-242
[6] Widyaningsih T D, Rukmi W D, Sofia, E, Wijayanti S D, Wijayanti, N, Ersalia, Rochmawati, N, Nangin, D 2016 Extraction of Glycosaminoglycans Containing Glucosamine and Chondroitin Sulfate from Chicken Claw Cartilage RJLS 3 3 181-189.
[7] Marzuki, A, Kasim, S, Arafah, N 2014 The Addition Effect of Sodium Hydroxide to Chondroitin Sulfate Level’s Retention Time of Pari’s Cartilage (Taeniura lymna) J. Phi. 9 239-245
[8] Zikri, A, Erlinawati, Rusnadi, I 2015 Performance Test of Rotary Dryer Based on Drying Thermal Efficiency of Wood Powder for Biopelet Production J. Chem. Engineering 21
[9] Ketaren, S 2005 Food Oil and Fat UI Press Jakarta Indonesia
[10] Burhanuddin, R 2007 Feasibility Study of Slaughter House Establishment in East Kuta Regency Deputy of East Kuta SME Resource Assessment Bali Indonesia
[11] Ibrahim H M Y 2009 Business Feasibility Study Rineka Cipta Jakarta Indonesia