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Formulation optimization of canned chicken in kacangma herbal soup using Response Surface Methodology

(Mengoptimumkan formulasi ayam kaleng di dalam sup herba kacangma menggunakan Kaedah Permukaan Gerak Balas)

H.P. Chua*, T. Zahrah** and A. Aminah***

Keywords: canned chicken, kacangma herbal soup, *Leonurus sibiricus*, formulation optimization, three-component constrained mixture

Abstract

Formulation of canned chicken in kacangma herbal soup, a traditional delicacy of Sarawak, was developed. The product was canned and retorted at 121 °C in an overpressure retort to achieve commercial sterility. A three-component constrained mixture according to a symmetrical-simplex interior design was used to determine the optimum formulation of the kacangma herbal soup. Results showed that a mixture with 82% blended ginger, 17% dried kacangma and 1% cornstarch gave a mean sensory score of more than 6.6 for taste, colour, texture, consistency and overall acceptability for the soup. Meanwhile, a score above 5.5 was given for aroma.

Introduction

Kacangma [*Leonurus sibiricus* Linn.; synonym *L. artemisia* (Lour.) S.Y. Hu] is a popular traditional medicinal herb of Sarawak. It is a herbaceous shrub from the mint family, Lamiaceae, with quadrangle erect branches and pink flowers. Kacangma grows to a height of 1.5 m. It is cultivated for sale in the market but sometimes found growing semi-wild on abandoned land and damp soil in villages (Chua 1998; Teo and Chua 2001). In Peninsular Malaysia, this herb is known as 'seranting', 'padang derman' and 'tebung aga' (Muhamad and Mustafa 1994). In Sarawak, kacangma is basically consumed as a herbal remedy for post-natal care especially to reduce body pain, emmenagogue and to hasten the contraction of uterus. The role of kacangma as an underutilized herb with potential economic value has been recognized. It has been stated as one of the important medicinal plants of Sarawak by the Malaysian Ministry of Agriculture (MOA 1995; Paulus and Lau 2004).

Due to the unique herbal flavour and aroma, kacangma's appeal extends beyond the confinement room. It has been used as a culinary ingredient among the people in Sarawak. Kacangma dish is a popular delicacy among the Sarawakians, thus there exists a prospect for kacangma to be cultivated on a large scale. Subsequently, efforts are made to increase the utilization

*Food Technology Research Centre, MARDI Kuching Station, Lot 411, Block 14, Santubong Road, Petra Jaya, 93055 Kuching, Sarawak, Malaysia

**Economics and Technology Management Research Centre, MARDI Headquarters, P.O.Box 12301, 50774 Kuala Lumpur, Selangor, Malaysia

***School of Chemical Sciences and Food Technology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

Authors' full names: Chua Hun Pin, Zahrah Talib and Aminah Abdullah

by developing kacangma herb into various special herbal products with commercial significance.

In product development, optimization is a procedure for developing the best possible product with maximum overall acceptability (Sidel and Stone 1983). This involved the initial step of evaluating and detecting critical potential ingredients that affect its sensory properties (Bomio 1994). Traditional experiment with 'one-variable-at-a-time' method has been claimed as inadequate due to its inability in finding the real overall optimum in the multi-ingredients food formulation. This method also lacks the ability to determine interactions between variables. Various approaches have been used to derive the optimum formulation and process parameters for food products.

Response Surface Methodology (RSM) is a collection of statistical methods that are useful in modelling and analysing problems in which response of interests is influenced by several variables. The function of RSM is to optimize the response and to quantify relationships among one or more measured responses and the vital input factors (Myers and Montgomery 2002). Shamsiah and Aminah (1995) used a three-level rotatable design to determine optimum conditions for the extraction of banana juice. Chuah et al. (2000) used a three-component constrained mixture design to develop chicken paprika in retort pouches, and Saniah and Hasimah (2008) used a central composite design to develop *Morinda citrifolia* citrus-flavoured drink.

This study was part of the project to develop value-added herbal products from kacangma herb. The objective of the study was to derive the optimum formulation of kacangma herbal soup for canned chicken using a mixture design.

Materials and methods

Raw materials

Skinless chicken thigh meats were purchased in frozen form from a local chicken slaughtering plant (Sarabef Sdn. Bhd.). The meats were transported to the laboratory in insulated containers containing crushed ice and were kept frozen at –20 °C until the following day.

Dried kacangma was obtained by drying the kacangma herbs planted in MARDI Kuching Station. Kacangma plants of 2-month maturity were used for producing the dried herbs. The aerial parts of the plant which consist of leaves and young stems were chopped and oven-dried at 55 °C in a force-air oven for 5–6 h until a final moisture content of below 6% (w/w).

Other ingredients such as cornstarch, ginger and seasonings were purchased from a local central market and kept in a refrigerator (4 °C) in their original package until further use.

Processing method

The skinless chicken thigh meats were cut into cubes with an average weight of 35 g per cube. The meat was then partially cooked by blanching in boiled water for 4 min and filled into cans (Metalpak, 300 mm x 305 mm). The cans were then topped up with hot kacangma-ginger herbal soup and seamed. This was followed by the process of retorting at 121 °C in an overpressure horizontal retort (APV Hill and Mills, 1219 mm diameter x 2438 mm straight body) to achieve commercial sterility. The processing method used is shown in *Figure 1*.

Sensory evaluation

All canned chicken in the herbal soup were steamed for about 5 min for sensory evaluation. While still hot, the samples were randomly presented to 10 trained panellists to evaluate the acceptability of the samples. The panellists were research staff of MARDI Kuching who had been trained to evaluate kacangma herbal aroma and bitter taste. A training session was conducted a week before the sensory evaluation commenced. Evaluation was conducted in individual booths in a sensory evaluation room. Panellists were instructed to evaluate

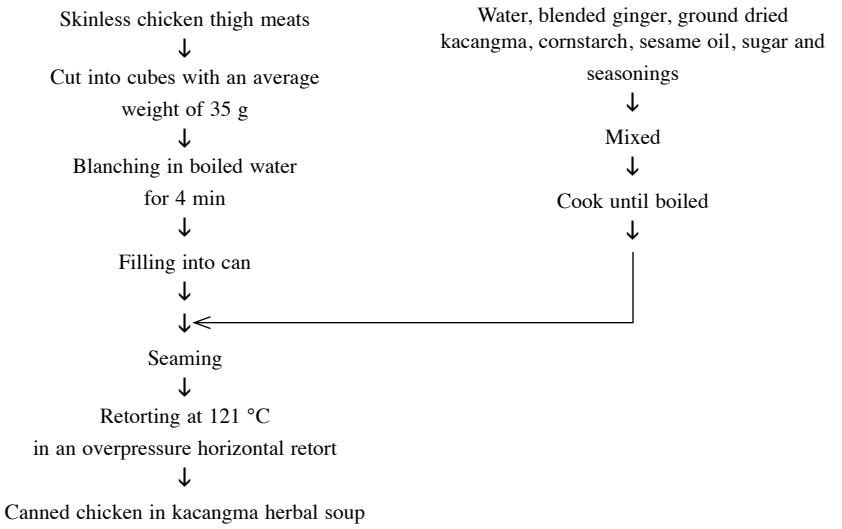

Figure 1. Processing of canned chicken in kacangma herbal soup

Table 1. Composition of kacangma-ginger herbal soup formulations in a three-component constrained symmetrical-simplex interior design evaluated for acceptability of sensory qualities

Formulation number*	Ingredient (%)		
	Blended ginger (*X1*)	Dried kacangma (*X2*)	Cornstarch (*X3*)
1	0.75	0.25	0
2	0.95	0.05	0
3	0.75	0.05	0.20
4	0.55	0.25	0.20
5	0.75	0.20	0.05
6	0.85	0.10	0.05
7	0.75	0.10	0.15
8	0.65	0.20	0.15
9	0.75	0.15	0.10
10	0.75	0.15	0.10

*Formulation numbers correspond to the numbers shown in *Figure 2*

all the samples for six sensory attributes i.e. taste, aroma, colour, texture, consistency and overall acceptability. Scores were assessed using a 9-point hedonic rating scale, ranging from 1 (dislike extremely), 5 (neither like nor dislike) to 9 (like extremely) (Larmond 1970).

Formulation optimization

The kacangma-ginger herbal soups were prepared in 10 formulations as outlined in *Table 1*. Amount of dried kacangma was based on safe dosage value achieved from a series of toxicological evaluations conducted earlier (Chua et al. 2006, 2007, 2008). Three ingredient variables affecting final characteristics of the kacangma herbal soup were formulated with the constraints on each variable as stated below:

Ingredient	Lower limit	Upper limit
Blended ginger (*X1*)	0	0.95
Dried kacangma (*X2*)	0.05	0.25
Cornstarch (*X3*)	0	0.20

Predictive models were used to generate contour plots for taste, aroma, colour, texture, consistency and overall acceptability. The model was fitted to the data for each of the sensory attributes. The estimates of the regression coefficients were obtained by setting the value of the intercept to zero and the best-fitting model for the attributes was chosen. The contour lines connecting the response points of equal values were plotted on the diagram of the contour space. This will enable finding of an optimum blend and other alternative blends that are of interest. The contour plots for the significant sensory attributes were then superimposed and regions of overlap were identified as optimum area (Palomar et al. 1994).

Experimental design

A three-component constrained mixture according to a symmetrical-simplex interior design (McLean and Anderson 1966; Snee 1975) was used in deriving the optimum formulation of the herbal soup. The mixture components consisted of blended ginger *(X1)*, ground dried kacangma *(X2)* and cornstarch *(X3)*. The lower and upper bound restrictions were placed on modified cornstarch *(X3)* and ground dried kacangma *(X2)* proportions thus limiting the desired mixture to a sub-region of the simplex coordinate system *(Figure 2)*.

Ten mixtures were tested in this experiment. Points 1, 2, 3 and 4 are the vertices of the region under study with 4 interior points i.e. 5, 6, 7 and 8. Points 9 and 10 are two replicated centre points. In each mixture of the formulation, the proportion of each ingredient is constrained within its lower and upper limits. The proportional

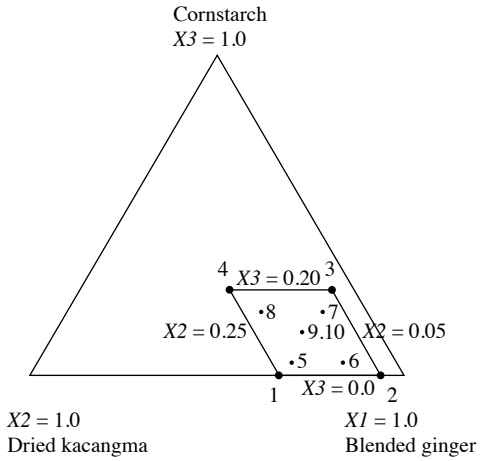

Figure 2. Constrained region in the simplex coordinate system defined by the following restriction: 0.00 < X1 ≤ 0.95, 0.05 < X2 ≤ 0.25, 0.00 < X3 ≤ 0.20. Numbers (1–10) represent 10 formulations and correspond to the numbers in Table 1

values of all ingredients must always be summed to 1.0 or 100% (i.e. *X1 + X2 + X3* = 1). On the other hand, the concentrations of other minor ingredients such as seasonings were kept constant.

Verification of experiment

Three formulation mixtures were selected to test the reliability of the model. Samples were produced using the method described earlier. Six sensory attributes i.e. taste, aroma, colour, texture, consistency and overall acceptability were evaluated. Scores were assessed by 10 trained panellists using a 9-point hedonic rating scale, ranging from 1 (dislike extremely), 5 (neither like nor dislike) to 9 (like extremely) (Larmond 1970).

Statistical and data analysis

Multiple regression analysis (SAS Inst. 1985) was used to fit a quadratic canonical polynomial model described by Scheffe (1958) as:

$$Yi = B1X1 + B2X2 + B3X3 + B12X1X2 + B13X1X3 + B23X2X3$$

where *Yi* is the predicted response variable; *B1, B2, B3, B12, B13* and *B23* are corresponding regression estimates for each linear and cross-product terms. *X1* is the proportion of blended ginger, *X2* is the proportion of dried kacangma and *X3* is the proportion of cornstarch. Due to the restriction of the mixture design (*X1* + *X2* + *X3* = 1), it was not possible to estimate the intercept (bo) and all the linear coefficients (bi). The regression model was not full rank. The intercept and parameters such as *X1X1, X2X2* and *X3X3* were set to zero and not included in the models. Adjusted R^2 was also redefined.

The sensory data recorded in the verification experiment were subjected to analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) to determine differences among the product samples.

Results and discussion

Formulation optimization

There were significant differences ($p \leq 0.05$) in all the six sensory attributes of the samples as outlined in *Table 2*. Dried kacangma (X2) had the most influence on the sensory attributes evaluated followed by cornstarch (X3). Blended ginger (X1) showed less influence. Formulation 2 received the lowest score in aroma, colour, texture, consistency and overall acceptability while formulation 4 had the lowest score in taste.

Table 3 showed the reduced quadratic canonical polynomials for each dependent

Table 2. Mean sensory scores for taste, aroma, colour, texture, consistency and overall acceptability of canned chicken in kacangma herbal soup

Formulation number*	Taste	Aroma	Colour	Texture	Consistency	Overall acceptability
1	4.4c	4.3de	5.2b	5.1c	5.9ab	5.6bc
2	3.3d	3.3f	3.1d	3.0d	2.4f	3.3f
3	3.8cd	4.8cde	4.1cd	3.1d	2.9f	4.6de
4	2.4e	4.0ef	3.9cd	3.4d	4.3de	4.1e
5	4.2c	5.3bc	4.8bc	6.6b	6.6a	6.1a
6	6.6a	6.6a	7.6a	7.5a	6.5a	6.9b
7	5.3b	6.0ab	5.8b	4.4c	4.0e	5.2cd
8	4.3c	5.2bcd	4.1cd	4.9c	4.9cd	5.1cd
9	6.0a	5.8ab	5.7b	5.9b	5.1bcd	5.8bc
10	6.1a	5.5bc	5.2b	6.1b	5.3bc	5.2bc

*Formulation numbers correspond to the numbers shown in *Table 1* and *Figure 2*
A 9-point hedonic scale was used: 1(dislike extremely), 5 (neither like nor dislike), and 9 (like extremely)
Means in the same column with the same letter are not significantly different at $p \leq 0.05$ using DMRT

Table 3. Reduced quadratic canonical polynomials for each dependent sensory attributes and overall acceptability of chicken in kacangma herbal soup containing proportions of blended ginger *(X1)*, dried kacangma *(X2)* and cornstarch *(X3)*

Dependent variables (Y)	Predictive model	Adjusted R^2
Taste	$Y = 0.70X1 - 166.24X2 + 4.09X3 + 240.00X1X2 + 189.41X2X3$	0.96
Aroma	$Y = 1.35X1 - 125.41X2 + 8.96X3 + 184.29X1X2 + 144.87X2X3$	0.95
Colour	$Y = 1.77X1 - 109.16X2 + 5.82X3 + 164.29X1X2 + 116.64X2X3$	0.93
Texture	$Y = 0.08X1 - 174.11X2 - 2.80X3 + 260.00X1X2 + 225.88X2X3$	0.96
Consistency	$Y = 0.19X1 - 102.54X2 + 0.50X3 + 168.57X1X2 + 123.86X2X3$	0.95
Overall acceptability	$Y = 1.56X1 - 94.56X2 + 7.73X3 + 150.00X1X2 + 88.24X2X3$	0.96

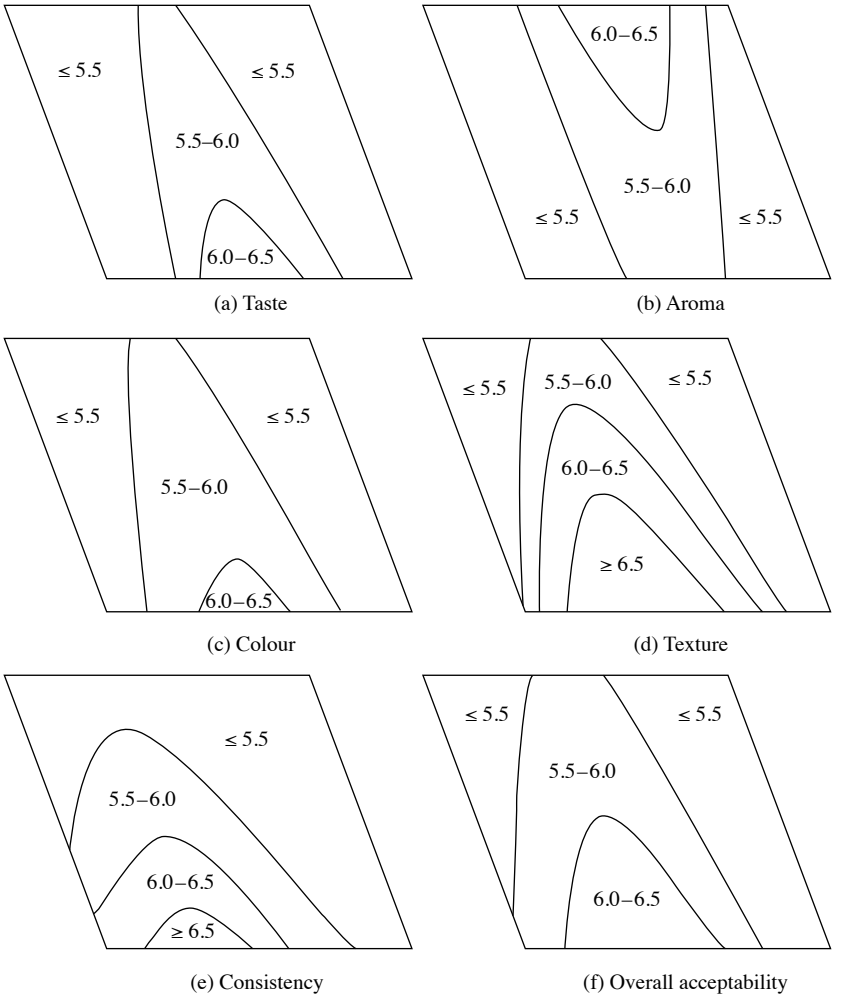

Figure 3. Contour plots for predicted acceptability values of (a) taste, (b) aroma, (c) colour, (d) texture, (e) consistency and (f) overall acceptability. Coordinates X1, X2, X3 and formulation numbers as shown in Table 1 and Figure 2

sensory attributes and overall acceptability of the canned product. The R^2 values for all dependent variables were high (range 0.93 to 0.96), indicating that the variation of the data was well explained by the regression model.

Overall acceptability Contour plots for predicted acceptability values of taste, aroma, colour, texture, consistency and overall acceptability are shown in *Figure 3*. By superimposing all the plots, the optimum region (acceptability score >6.0) which satisfied the panellists is identified as shown in *Figure 4*. For the 10 mixtures tested in this experiment, formulation 6 which contains a mixture of 85% blended ginger, 10% dried kacangma and 5% cornstarch was most acceptable in terms of overall acceptability.

Taste and colour Formulation with 13–19% dried kacangma, lower percentage of cornstarch (<3%) and higher percentage of blended ginger (>79%) would yield a product with predicted acceptability score of

6.0–6.5. Higher content of dried kacangma in the formulation would yield a product with strong herbal taste and dark colour which were unacceptable to the panellists.

Aroma Plots of aroma showed an opposite trend compared to the other five sensory attributes. Products with predicted acceptability score of 6.0–6.5 was the formulation with higher percentage of cornstarch (>11%).

Texture and consistency Formulations 2 and 3 with lesser dried kacangma (0.05%) showed the lowest score (<2.9). Higher content of dried kacangma gave a product with higher acceptability score in terms of texture and consistency.

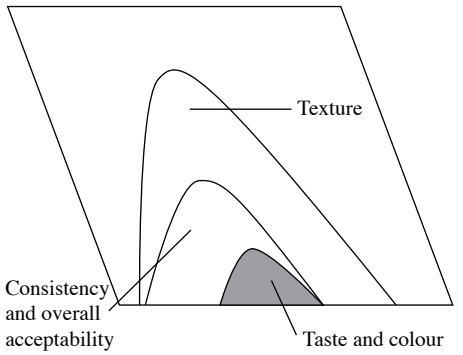

Figure 4. Superimposed plot shows optimum region (shaded) of blended ginger (X1), ground dried kacangma (X2) and cornstarch (X3) that would yield chicken in kacangma herbal soup with score ≥6.0 on a 9-point hedonic scale

Verification of experiment

All formulation combinations (*Figure 4*) containing less than 5% cornstarch were predicted to produce products with sensory score ≥ 6.0 except for attribute aroma where a higher content of cornstarch produced a higher score in aroma.

In this experiment, formulations that were rated with scores of 5.5 or higher for taste, aroma, colour, texture, consistency and overall acceptability were used to derive an optimum. The reliability of this model was tested by three selected formulations namely I, II and III. Formulation I is most similar to the traditional formulation. II represents formulation outside optimum region whereas III represents formulation in the optimum region. From the mean sensory scores shown in *Table 4*, it was found that formulation III with a mixture of 82% blended ginger, 17% dried kacangma and 1% cornstarch gave a mean sensory score of >6.6 for all sensory attributes evaluated except for aroma. However, the score for aroma was still above 5.5.

Conclusion

From all the sensory attributes evaluated, the acceptability of the canned chicken in kacangma herbal soup was found to be greatly influenced by the levels of dried

Table 4. Mean sensory scores for taste, aroma, colour, texture, consistency and overall acceptability of selected formulations of canned chicken in kacangma herbal soup

Formulation number *	Taste	Aroma	Colour	Texture	Consistency	Overall acceptability
I	5.6	5.5	5.6	6.4	6.1	6.4
II	6.3	5.6	5.6	6.3	5.9	6.4
III	6.9	5.8	7.4	7.1	6.6	7.3

*Formulation numbers corresponding to:
I : *X1* = 0.77, *X2* = 0.19, *X3* = 0.04
II : *X1* = 0.79, *X2* = 0.13, *X3* = 0.08
III : *X1* = 0.82, *X2* = 0.17, *X3* = 0.01
X1 = blended ginger, *X2* = ground dried kacangma, *X3* = constarch
A 9-point hedonic scale was used: 1(dislike extremely), 5 (neither like nor dislike), and 9 (like extremely)

kacangma and cornstarch in the herbal soup formulation. A mixture of 82% blended ginger, 17% dried kacangma and 1% cornstarch would give a mean sensory score of >6.6 for taste, colour, texture, consistency and overall acceptability.

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Abstrak

Formulasi masakan ayam kaleng di dalam sup herba kacangma, sejenis hidangan tradisional Sarawak, telah dibangunkan. Produk ini telah ditinkan dan diretort pada 121 °C dalam retort tekanan untuk mencapai pensterilan komersial. Campuran terbatas tiga komponen mengikut reka bentuk dalaman simetrikal-simpleks telah digunakan untuk penentuan formulasi optimum bagi sup herba kacangma. Kajian menunjukkan campuran 82% halia kisar, 17% kacangma kering dan 1% kanji jagung telah memberikan skor nilai rasa melebihi 6.6 untuk rasa, warna, tekstur, kekentalan dan penerimaan keseluruhan sup berkenaan. Manakala, skor melebihi 5.5 diperoleh untuk aroma.

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