Corn Starch Incorporated Gomatofu: Textural and Sensory Quality

Deep N. Yadav[1,*], Jyotsana Dhasmana[2], Monika Sharma[1] and Yogesh Kumar[1]

[1]*Central Institute of Post Harvest Engineering and Technology, Ludhiana-141 004, Punjab, India*

[2]*Department of Food Technology, Jamia Hamdard, New Delhi*

Abstract: Gomatofu is a traditional Japanese food and is one of the mixed gels consisting of kudzu (arrowroot) starch and sesame. In this study, an attempt has been made to replace the kudzu starch with corn starch. Central composite rotatable design (CCRD) of response surface methodology was used to optimize the level of independent variables viz., sesame oil (1.5-3.5g/100 ml sesame milk), corn starch (90–110g/100g defatted sesame flour) and water content (330-350 ml/100g defatted sesame flour). Five responses, *i.e.* hardness, springiness, gumminess, chewiness and overall acceptability were evaluated. Hardness of gomatofu ranged between 0.85 to 3.62 N, springiness, 0.45 -1.82 mm, gumminess 0.26 -2.48 N and chewiness from 0.16 to 4.52 Nmm. Overall acceptability of gomatofu samples ranged between 5.3- 8.5. The effect of all the independent factors was significant on all the responses. Both oil and water content inversely correlated with all the responses while, the effect of corn starch was positive. The interaction effect of oil and corn starch was positive on hardness and overall acceptability, while negative on springiness, gumminess and chewiness. The optimized formulation contained sesame oil 2.2 ml/100 ml sesame milk, corn starch 99.9 g/100g defatted sesame flour and water 1001.3 ml/ 100g defatted sesame flour. Corn starch incorporated optimized gomatofu had protein 7.5, fat 10.9, ash 1.1 and carbohydrate 80.53 % (db).

Keywords: Corn starch, Gomatofu, Sesame, Texture.

INTRODUCTION

Sesame (*Sesamum indicum L.*) is cultivated in several countries such as India, Sudan, China and Burma and contributes about 60% of total world production [1]. It is an important source of oil (44–58%), protein (18–25%), carbohydrate (~13.5%) and ash (~5%). The seeds are exceptionally rich in iron, magnesium, manganese, copper, calcium, vitamin B_1 and vitamin E [2]. It also contains lignans, including sesamin, which are phytoestrogens with antioxidant and anti-cancer properties. Sesame seeds are sometimes added to breads, hamburger buns, sprinkle-ed onto some sushi style foods, roasted and used for making the flavouring *gomashio*.

Gomatofu (sesame tofu) is one of the traditional Japanese healthy foods and is representative of all shojin (vegetarian) dishes. Gomatofu, one of the mixed gels consisting of kudzu (arrowroot) starch and sesame, possesses an extremely unusual textural characteristic which is soft, smooth, and springy. The textural properties are greatly influenced by starch and sesame milk contents or preparing conditions. Sato [3, 4] investigated the effect of preparing conditions, the mixing rates and cooking times, on the physical properties of gomatofu and reported that kudzu starch gel had a thick branched structure, and had fibrous microstructure which surrounds globular sesame oils.

Starch is widely used in the food industry, either as a main raw material or as a food additive. As an additive, starch contributes to the thickening and stabili-zing effects and texture modification in food [5]. Most of the starch produced worldwide is derived from corn. Corn provides a high-quality starch used widely in the food industry in many applications requiring particular viscosities and textures. The ready availability of corn at relatively low and steady prices, its storability from season to season, its ease of transportation and handl-ing, and its high starch content led naturally to the development of commercial processes for recovery of corn starch.

Previous studies on the effect of preparing conditions, the mixing rates and cooking times, on the physical properties of gomatofu and the effect of sesame oil contents on the mechanical properties of gomatofu [6] were taken into consideration. However, preparation of gomotafu with starch sources other than kudzu has been limited. Thus, in this study, an attempt has been made to replace the traditional kudzu (arrowroot) starch used to prepare gomatofu with corn starch. The level of ingredients viz. sesame oil content, corn starch and water content were optimized using response surface methodology to develop corn starch incorporated sesame based gomatofu.

MATERIALS AND METHODS

Materials

Sesame seeds, corn starch and sesame oil were procured form the local market of Ludhiana, Punjab,

*Address correspondence to this author at the Central Institute of Post Harvest Engineering and Technology, Ludhiana-141 004, Punjab, India; Tel: +91 1612313186; Fax: +91 1612308670; E-mail: dnyadav1977@yahoo.co.in

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India. The samples were manually cleaned to remove foreign matters such as; dust, dirt, broken and imamture grains.

Experimental Design

Central Composite Rotatable Design (CCRD) was used to design the experiments with three independent parameters using Design expert 8.0.5 software. Twenty sets of experiments were performed taking into account three independent variables viz., sesame oil content: 1.5-3.5g/100 ml sesame milk, corn starch: 90–110g/100g defatted sesame flour and water content: 330-350 ml/100g defatted sesame flour. The measured responses were hardness, springiness, gumminess, chewiness and overall acceptability (OAA). There were six experiments at centre point to calculate the repeatability of the method. The levels of different independent variables and plan of experiment is presented in Table **1**.

Preparation of Gomatofu

Gomatofu was prepared from defatted sesame flour following the method of Sato [7]. Sesame oil, corn starch and water were added as per the experimental plan based on 100g of defatted sesame flour. The suspension was prepared using a simmering method at the mixing rate of 250 rpm for 25 min of cooking time, and they were immediately poured into a glass ring case (20 × 20 mm). After samples were cooled at room temperature for 1 h, they were used for measurement.

Texture Profile Analysis

Texture measurements of gomatofu samples were performed at room temperature using the texture analyzer (TA-Hdi), (Stable Micro systems, UK). Prior to analysis, samples were allowed to equilibrate to room temperature. Texture profile analysis [8] was performed using five pieces of each sample (2.5×2.5×2 cm), which were compressed twice with a cylinder probe

Table 1: Central Composite Rotatable Design with Values of Independent and Dependent Variables of Gomatofu

Exp	Variables			Responses				
	A	B	C	Hardness, N	Springiness, mm	Gumminess, N	Chewiness, N mm	OAA
1	14.0	110.0	330.0	2.54	1.31	1.45	1.90	7.4
2	14.0	90.0	330.0	1.10	0.92	0.71	0.65	6.1
3	16.0	116.8	340.0	3.59	1.82**	2.48**	4.52**	8.5**
4	18.0	110.0	350.0	3.10	1.44	1.48	2.13	8.0
5	16.0	100.0	340.0	1.50	0.84	0.40	0.33	6.5
6	18.0	90.0	330.0	0.85*	0.7	0.63	0.44	5.7
7	16.0	100.0	356.8	2.52	1.45	1.03	1.49	7.8
8	19.4	100.0	340.0	2.24	1.26	0.90	1.13	7.6
9	16.0	83.2	340.0	2.88	1.39	1.64	2.28	8.1
10	16.0	100.0	340.0	1.97	0.90	0.86	0.77	6.9
11	16.0	100.0	340.0	0.89	0.45*	0.35	0.16*	5.3*
12	16.0	100.0	323.2	2.14	1.38	1.55	2.14	8.3
13	16.0	100.0	340.0	3.62**	1.25	1.68	2.09	8.2
14	16.0	100.0	340.0	1.58	0.65	0.26*	0.17	7.3
15	12.6	100.0	340.0	2.12	1.07	0.86	0.92	7.5
16	18.0	90.0	350.0	2.10	1.08	0.87	0.94	7.4
17	14.0	90.0	350.0	2.15	1.06	0.88	0.93	7.5
18	14.0	110.0	350.0	2.10	1.07	0.86	0.92	7.6
19	16.0	100.0	340.0	2.14	1.05	0.86	0.90	7.6
20	18.0	110.0	330.0	2.15	1.06	0.87	0.92	7.6

A-Oil content (g/100ml sesame milk); B- corn starch (g/100g defatted sesame flour); C- water content (ml/100g defatted sesame flour); OAA- overall acceptability, *- lowest value; ** - Highest value.

P75. A time of 2 s was allowed to elapse between two compression cycles. The cross-head moved at a constant speed of 1 mm/s. From the resulting curve, hardness, springiness, chewiness, and gumminess were determined.

Sensory Analysis

Sensory quality characteristics of gomatofu samples were evaluated for different sensory attributes by a group of twelve semi-trained panellists from staff and students of the institute. Four samples (with three digits codes) were presented before the panelists at one time. Care was taken to maintain the sensory environment at 20±2 °C. The panellists were asked to rate the samples using nine point hedonic scale [9] from liked extremely (9) to disliked extremely (1) for overall sensory acceptability (OAA).

Proximate Composition

The moisture (method 44-19), protein (method 46-12), fat (method 30-25) and ash (method 8-01) contents of samples were determined using AACC [10] standard methods. Carbohydrate was calculated by subtracting the sum of moisture, protein, fat and ash from 100 [11]. Total calories were calculated by multiplying protein, carbohydrates and fat content by 4, 4 and 9, respectively. All reagents used for chemical analysis were of analytical grade.

Statistical Analysis

Response surface methodology (RSM) was adopted in experimental design and analysis [12]. Multiple regression analysis was used to fit the model, represented by an equation, to the experimental data. Maximization and minimization of the polynomials thus fitted was done by numeric techniques, using the numerical optimization technique given in the software package (Design expert (r) software version 8.0.5).

For the analysis of experimental design by the response surface, it was assumed that n-mathematical functions, f_k (k=1, 2….. n), Y_k in terms of m independent processing factors Xi (i=1, 2, ……………, m) existed for each response variable.

$$Y_k = f_k(X_1, X_2, \ldots, X_m) \qquad (4)$$

In this case, n=5, m=3

Full second-order equation was fitted in each response to describe it mathematically and to study the effect of variables. The equation was as follows:

$$Y_k = \beta_0 - \sum_{i=1}^{m} \beta_i X_i + \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \beta_{ij} X_i X_j + \sum_{i=1}^{m} \beta_{ii} X_i^2 \qquad (5)$$

where, Y_k=response variable, β_0 is the value of the fitted response at the centre point of the design *i.e.* (0,0) and β_i, β_{ij}, β_{ii} are the linear, quadratic and interactive regression coefficients, respectively. X_i and X_j are the coded independent variable.

Numerical optimization technique of the Design–Expert software (8.0.5) was used for simultaneous optimization of the multiple responses. Responses obtained were analyzed to visualize the interactive effect of independent parameters on quality attributes

Table 2: Regression Coefficient of Full Second Order Model for Textural Properties and Overall Acceptability of Gomatofu and their Significance

Coefficients	Hardness, N	Springiness, mm	Gumminess, N	Chewiness, Nmm	OAA
β_0	0.75605	4.11128	5.91195	10.30959	-10.17906
β_1	-3.85526*	-1.06432*	-2.71769*	-4.47489*	-2.99734*
β_2	0.53445*	0.024313*	0.088896*	0.14592*	0.58825*
β_3	-0.036767*	-0.00587735*	-0.00966557*	-0.018657*	-0.018271*
β_{12}	0.016500	-0.000525	-0.0077500*	-0.020060*	0.017500*
β_{13}	0.0012375	0.00054750	0.002300*	0.00421971*	0.001000*
β_{23}	-0.00007875	0.00001725	-0.000111250*	-0.000279354*	0.0000250
β_{11}	0.10452	0.074634*	0.14924*	0.27367*	-0.041092
β_{22}	-0.00216865*	-0.0000721398	0.00043701*	0.0013970*	-0.00288579*
β_{33}	0.0000166741*	0.000000516039	0.00000498882*	0.0000133733*	0.00000472964
R^2, %	95.3	92.1	99.6	97.6	98.9
F-value	22.27	12.95	284.47	44.47	102.27

Significant * p≤0.05; OAA: overall acceptability; F-value- Fisher test calculated value.

of the gomatofu. The adequacy of the model was tested using F-ratio, coefficient of correlation (R^2) and lack of fit test.

RESULTS AND DISCUSSION

The proximate composition of sesame seeds used to prepare gomatofu were moisture 2.6, protein 23.3, fat 48.9, ash 3.7 and carbohydrate 21.5%.

Effect of Variables on Responses

The values of different responses of gomatofu as affected by ingredient level are mentioned in Table **1**. The hardness of gomatofu ranged between 0.85 to 3.62 N, springiness, 0.45 -1.82 mm, gumminess 0.26 - 2.48 N and chewiness from 0.16 to 4.52 Nmm. Overall acceptability in gomatofu samples ranged between 5.3-8.5. Oil and water content had significant ($P \leq 0.05$) negative effect on hardness of the gomatofu samples, while variable corn starch had significant ($P \leq 0.05$) positive impact on the hardness at linear level. The full second order regression coefficients for the variables have been presented in Table **2**. The effect of oil and water was negative, whereas the corn starch positively affected the springiness at linear level. The response surface graphs for the combined effect of levels of different ingredients on hardness (a-c) and springiness (d-f) are given in Figure **1**. The gumminess was positively affected by the corn starch and negatively affected by oil and water at linear level. Oil and water had a significant negative effect on chewiness at linear level, whereas it was affected positively by corn starch at linear level. The response surface graphs for the combined effect of levels of different ingredients on gumminess (a-c) and chewiness (d-f) are given in Figure **2**. The overall acceptability was positively affected by the variable corn starch at linear level, whereas oil and water had negative effect on OAA at linear level. The graphical representation of OAA (a-c) as affected by the level of different ingredients is given in Figure **3**.

The interaction effect of oil and corn starch was non-significantly ($P > 0.05$) positive on hardness, while negative on springiness. On the other hand, interaction effect of oil and corn starch was significantly ($P \leq 0.05$) positive on overall acceptability, while negative on gumminess and chewiness. When the interaction effect of corn starch and water was evaluated, it significantly ($P \leq 0.05$) affected only gumminess and chewiness. The interaction of oil and water content significantly

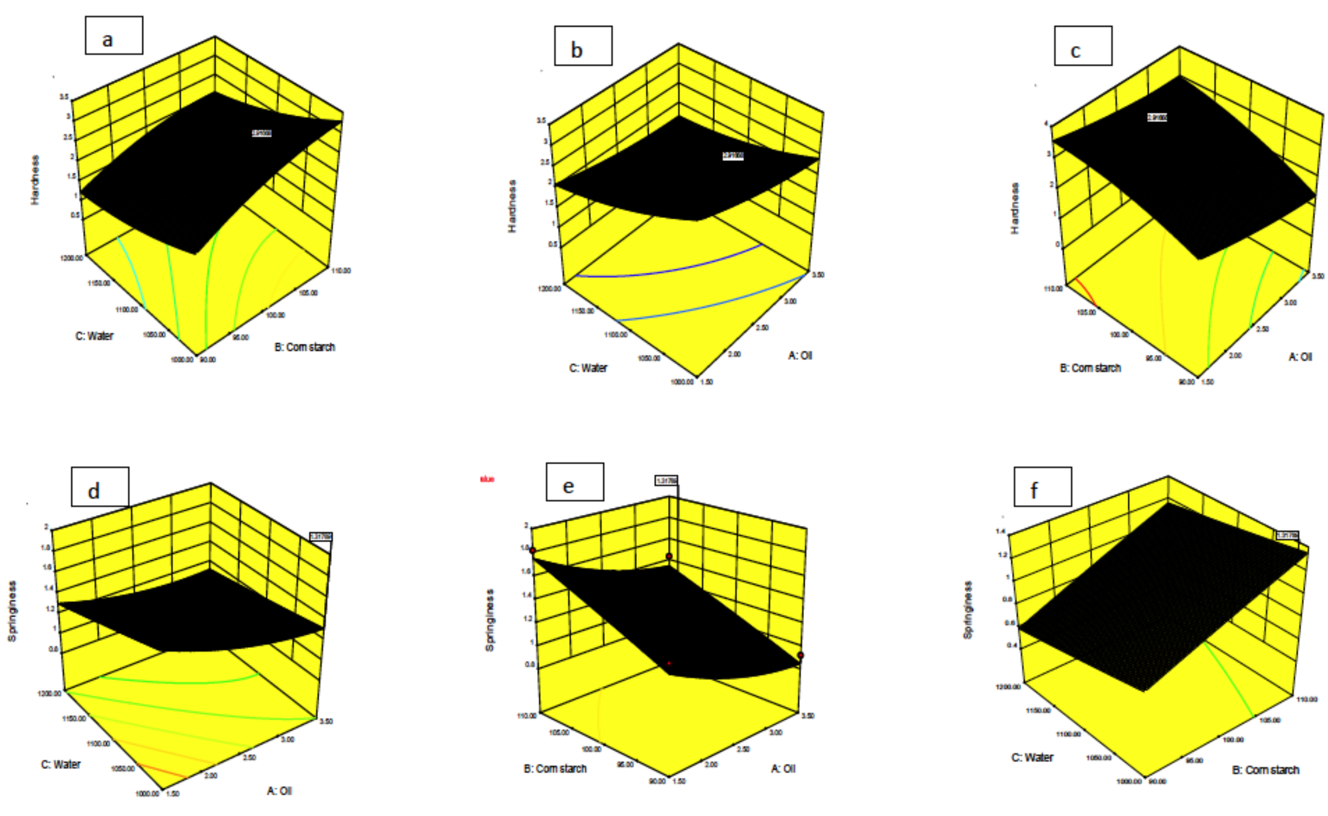

Figure 1: Response surface plots showing the effect of variables on hardness **(a-c)** and springiness **(d-f).**

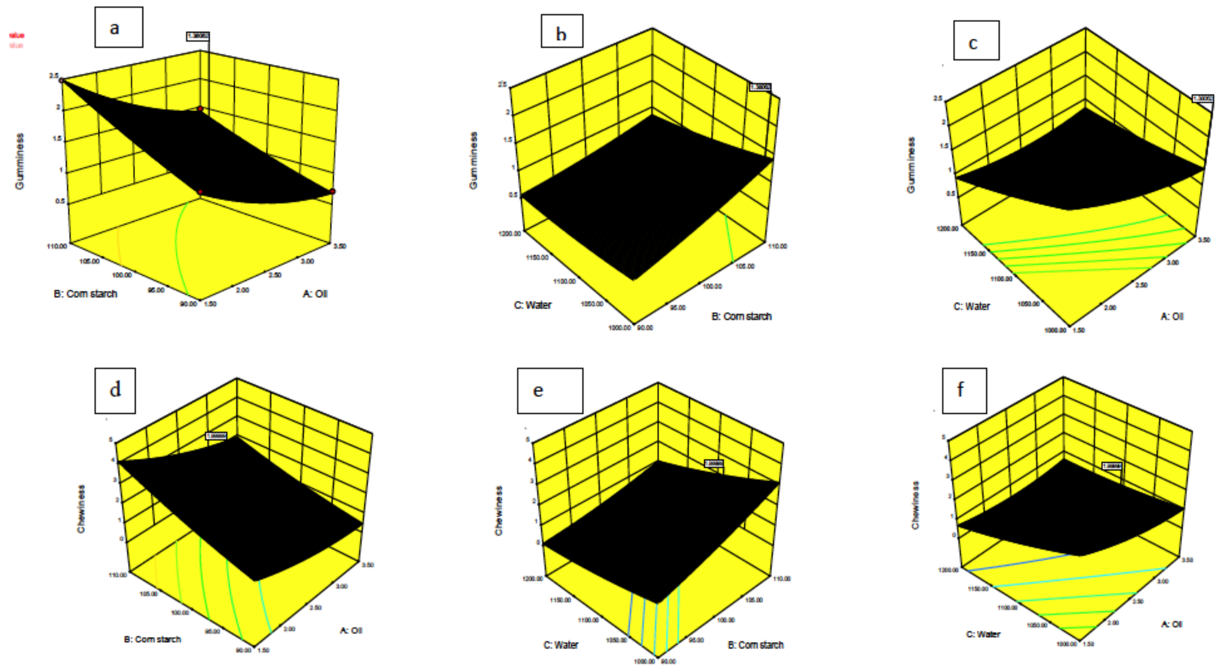

Figure 2: Response surface plots showing the effect of variables on gumminess (**a-c**) and chewiness (**d-f**).

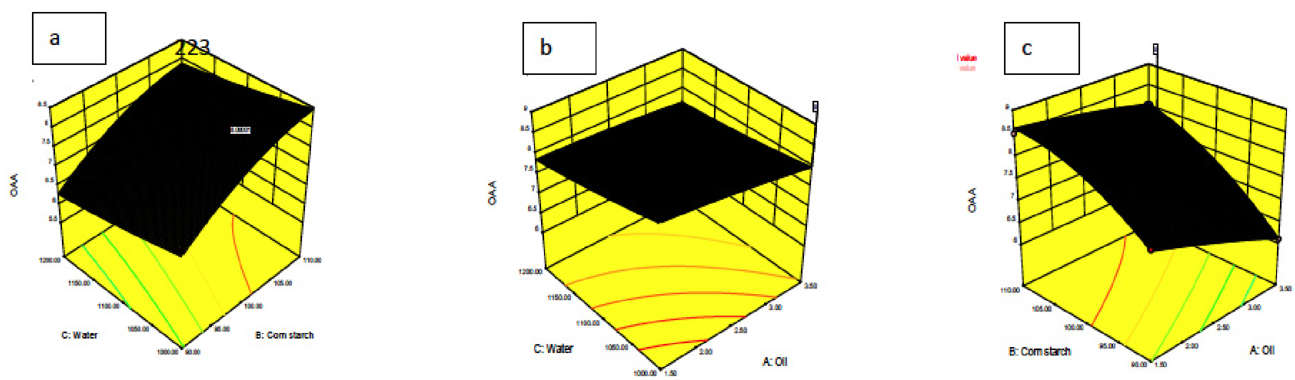

Figure 3: Response surface plots showing the effect of variables on overall acceptability (**a-c**).

(P≤0.05) affected gumminess, chewiness and overall acceptability.

At quadratic level, significant (P≤0.05) effect was observed on hardness for corn starch (negative) and water (positive). At quadratic level, oil, corn starch and water had significant (P≤0.05) positive effect. At quadratic level, variables oil, corn starch and water had significant (P≤0.05) positive effect for chewiness.

Validation of Models

The model was generally considered adequate when (a) the calculated F-ratio was more than that of table value (3.02 at 5 % level of significance) and (b) the R^2 value was more than 80% [13]. The effect of variables at linear, quadratic and interactive level of the responses was described using significance at 5% level of confidence. A best-fit equation was developed using stepwise regression analysis. The sign and magnitude of the coefficient of linear and interactive terms indicated the effect of variables on response. The positive coefficient in linear term indicated increased response with increase in variable level, while negative coefficient showed decreased response value. In interaction, the level of one variable could be increased while decreasing the level of other

Table 3: Constraints Criteria for Optimization, Solution Along with Predicted and Actual Response Values

Constraints	Goal	Lower Limit	Upper Limit	Importance	Solution	Actual Response Value
Oil, g/100ml sesame milk	in range	1.5	3.5	3	2.18	-
Corn starch, g/100g dsf	in range	90	110	3	99.91	-
Water, g/100g dsf	in range	1000	1200	3	1001.27	-
Hardness, N	target = 3	0.85	3.62	5	2.92	2.90
Springiness, mm	target = 1.5	0.45	1.82	4	1.29	1.25
Gumminess, N	minimize	0.26	2.48	4	1.47	1.42
Chewiness, Nmm	target = 2	0.16	4.52	5	1.99	2.00
OAA	target = 8	5.3	8.5	5	8.0	8.2

interacting variable. The F values higher than the table value for all the responses indicates the adequacy of the model. Further, the coefficient of correlation was also higher than 0.9 in all the cases.

Optimization of Level of Independent Variables

For the optimization of variables level, the responses *i.e.*, Hardness, Springiness, Gumminess, Chewiness and Overall acceptability were selected on the basis that these responses had direct effect on the acceptability and quality of the gomatofu. These responses were used for the numerical optimization of the variables and the criteria used along with predicted and actual values of the responses have been presented in Table **3**. By using the given criteria, only one solution was obtained *i.e.*, oil 2.18ml/100 ml sesame milk, corn starch 99.91g/100g defatted sesame flour and water 1001.27ml/ 100g defatted sesame flour. The oil content for the *kudzu* based gomatofu was reported to be 3.4 - 6.4% [6] which is higher than gomatofu (2.18% Oil) prepared in our study using optimized level of ingredients. Gomatofu was prepared based on solution obtained and responses were measured. Hardness, springiness, gumminess and chewiness of optimized samples were 2.90 N, 1.25 mm, 1.42 N and 2.00 Nmm, respectively. The hardness and gumminess of gomatofu prepared from raw sesame using *kudzu* starch was reported [6] as 1.83 and 1.37 N, respectively. This indicates that corn starch may be a potential alternative for *kudzu* starch. The measured responses were very much close to the predicted ones (Table **3**), reconfirming the adequacy of the models. Therefore, the optimized level of conditions was recommended for the preparation of gomatofu. The optimized gomatofu sample was also evaluated for proximate composition and values were protein 7.5%, fat 10.8%, ash 1.2% and carbohydrate 80.5 % on dry weight basis.

CONCLUSION

On the basis of the above results it was concluded that a high quality gomatofu can be prepared by replacing kudzu starch (arrowroot) with corn starch. An acceptable quality gomatofu can be prepared by using the recommended set of conditions *i.e*. oil 2.2 ml/100 ml sesame milk, corn starch 99.9 g/100g defatted sesame and water 1001.3 ml/ 100g defatted sesame flour. The oil had significant negative effect on the overall acceptability of the gomatofu however, it increases the quality of the gomatofu when used in small amounts *i.e*. 2-3 ml but thereafter decreases the acceptability when added in higher amounts by affecting the textural properties. The corn starch had significant positive effect on the overall acceptability of gomatofu samples. This study will be useful for preparation of gomatofu by using corn starch in place of arrowroot and open the door for exploring the other starch sources.

REFERENCES

[1] Abou-Gharbia HA, Shehata AAY, Shahidi F. Effect of processing on oxidative stability and lipid classes of sesame oil. Food Research International 2000; 33: 331–340.

[2] Kahyaoglu T, Kaya S. Modelling of moisture, colour and texture changes in sesame seeds during the conventional roasting. Journal of Food Engineering 2006; 75: 167–177.

[3] Sato E, Miki E, Gohtani S, Yamano Y. The effect of sesame contents on viscoelasticity and microstructure of gomatofu (sesame tofu). Journal of the Japanese Society for Food Science and Technology 1995a; 42: 871-877.

[4] Sato, E., Miki, E., Gohtani, S., & Yamano, Y. The effects of preparing conditions on the physical properties and microstructure of gomatofu. Journal of the Japanese Society for Food Science and Technology 1995b; 46: 737-747.

[5] Eliasson AC, Gudmundsson M. Starch: physicochemical and functional properties. Carbohydrates in Food Second Edition, Taylor & Francis, Boca Raton, 2006; pp 391-469.

[6] Sato E, Shinbo Y, Watanabe M, Nishinari K. The effect of sesame oil contents on the mechanical properties of gomatofu (sesame tofu). Journal of the Society of Rheology, Japan, 2005; 33(2): 101-108.

[7] Sato E. Effects of different kind of sesame materials on the physical properties of gomatofu (sesame tofu). Food Hydrocolloids 2003; 17: 901-906.

[8] Bourne MC. Texture profile analysis. Food Technology 1978; 32: 62–66.

[9] Larmond, E. Laboratory Methods for Sensory Evaluation of Foods. Publication No. 1637, Department of Agriculture, Ottawa, Canada, 1977; Pp. 17-22.

[10] AACC. Approved methods of the AACC, 10th edn. St. Paul, USA: American Association of Cereal Chemists, 2000.

[11] Merrill, A.L. Watt, B.K. Energy value of foods: basis and derivation. In: *Agriculture Handbook* No. 74, United States Department of Agriculture, Washington, USA, 1973; Pp. 2–4.

[12] Khuri AI, Cornell JA. Response Surfaces: design and analysis. Marcel Dekker, New York, pp 127–145, 1987.

[13] Henika RG. Use of response surface methodology in sensory evaluation. Food Technol 1982; 36(11): 96–101

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