The Journal of Agricultural Sciences - Sri Lanka
Vol. 16, No. 2, May 2021. Pp 226-236
http://doi.org/10.4038/jas.v16i2.9328

Optimization of Composite Fruit Peel Powder as a Texture Modifier for Fat Free Set Yoghurt: A Mixture Design Approach

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Received: 6th February 2020 / Accepted: 18th February 2021

ABSTRACT

Purpose: *Fruit waste (FW) is a leading food waste type generates globally. Industrial management of such FW is a great challenge. Since those wastes are rich in nutrients, phytochemicals, and other functional compounds, they can be reused by value addition. In the present study, composite fruit peel powder was formulated and optimised from the FW collected from leading fruit processing industries in Sri Lanka. This powder was utilized as a texture modifier in fat free yoghurt to minimise the whey off.*

Research Method: *The experiment was carried out using an optimal mixture design of response surface methodology (Design Expert, 8.0.3.1 trial version) for sixteen composite samples. The independent variables were passion fruit peel (FFPP) (60.00–70.00 g/100 g), pineapple peel (PPP) (20.00–30.00 g/100 g), and orange peel (OPP) (10.00–20.00 g/100 g) powders. The dependent variables were proximate composition (fibre, fat, and ash contents), physiochemical (colour values), and technological (bulk density, swelling capacity, oil holding capacity, water holding capacity) properties.*

Findings: *Results of the ANOVA test showed that the model and model terms significantly affect (P≤0.05) all the parameters except bulk density and oil holding capacity. The contour plots showed that the orange peel largely contributes to the fibre, fat, ash contents and redness (a*) while passion fruit peels highly contribute to the lightness (L*) and water holding capacity. PFPP (60%), OPP (20%) and PPP (20%) were selected as optimum blend due to high fibre content, water holding capacity, and lightness along with less fat content.*

Originality/Value: *Accordingly, it is possible to optimise some quality parameters of fruit peel powders by compositing them.*

Keywords: *composite powder, fruit peel, mixture design*

INTRODUCTION

Product development is the lifeblood of the food industry (MacFie, 2007). This covers the complete process of bringing a new or modified product to the market stage from idea generation. In this process, suitable experimental designs and statistical methods are vital. The experimental design is a systematic approach to apply statistical methods to experimental processes (e.g. production process/prototype development stages) to improve input-output factors and process parameters (Anon, 2018). This is usually used as a methodology for selecting the levels of independent factors that provide the least variation on the required quality (Anon, 2018). Computer aided statistical experimental designs will accelerate food development cycles and reduce research and labour costs (Hu, 2017).

In food product development, the factorial design is used to identify the factors affecting certain parameters. Response surface methodology

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(RSM) is used to optimize such factors in order to obtain the most appropriate value for response. RSM reduces the number of experimental trials required in multi-factor experiments (Bai *et al.,* 2015). Mixture design, a special type of RSM, is a very effective method of determining the proportions of variables (ingredients) of a blend. This has been implemented successfully in real-world problems (Sahin, Demirtas, & Burnak, 2016) such as optimising food additives content (Gama *et al.,* 2019) and bioactivities of functional foods (Bertin *et al.,* 2020).

Nearly 80% of local fruit manufacturing industries either incinerate/bury their fruit wastes. Among them, fruit peels are the major waste type (Dias *et al.,* 2020b). They are rich in nutritional and functional properties (Dias *et al.,* 2020c; Gheribi *et al.,* 2019; Lasano *et al.,* 2019), hence, have a possibility to add values and recycle within the food industry. Numerous researches evaluate the potentials of add value to the fruit peels (Ali *et al.,* 2019; de Faria Arquelau *et al.,* 2019; Hanani *et al.,* 2019). Modifying and enhancing the yoghurt texture by adding fruit peel powders like pineapple and passion fruit along are also reported (do Espírito Santo *et al.,* 2012; Sah *et al.,* 2016). By compositing peel powders, a researcher may combine different functional characteristics together which would be valuable for industrial end users.

Eliminating milk fat is vital in the dietary management of non-communicable diseases. However, texture deformation and large whey separation were observed in yoghurt as milk fat and added sugar elimination (Dias *et al.,* 2020a). Fibre rich peel powders usually having high water holding capacity, hence can be used to minimize additional whey off. The current study is focused on developing fruit peel powder composite with optimum such properties with appealing colour to the incorporation.

MATERIALS AND METHODS

Proximate composition, physiochemical, and technological properties

Proximate compositions were determined by calculation methods based on the values obtained for individual peels by AOAC methods (Howitz, 2000). The colour of the samples was measured using a Hunter Lab colour meter (CR 400, Conika Minolta, Japan).Colour was expressed in Hunter Lab units L*, a* and b*, where L* indicates lightness, a* indicates hue on a green (–) to red (+) axis, and b* indicates hue on a blue (–) to yellow (+) axis (Ozcan and Kurtuldu, 2014). Technological properties were evaluated according to the methods of Acuna *et al.* (2012) with slight modifications. Yoghurt formulation and its quality attributes were reported in a separate paper (Dias *et al.,* 2020d).

Statistical analysis

The experimental design was carried out using the optimal mixture design of response surface methodology (Design Expert, 8.0.3.1 trial version) which resulted in sixteen composite samples (Table 01). The independent variables were passion fruit peel (FFPP) (60.00–70.00 g/100 g), pineapple peel (PPP) (20.00–30.00 g/100 g), and orange peel (OPP) (10.00–20.00 g/100 g) powders. The dependent variables were the proximate composition (fibre, fat, and ash contents), physiochemical (colour values), and technological (bulk density, swelling capacity, oil holding capacity, water holding capacity) properties.

In this study, interaction effects of passion fruit peel (A), orange peel (B), and pineapple peel (C) on selected dependant variable were tested. The test hypothesis as follows; Ho = Interaction effects of peel powders on the dependant variable are significant

H_A = Interaction effects of peel powders on the dependant variable are not significant

If the p value $p \leq 0.05$ then, H_o (Null hypothesis) will be accepted and H_A (alternative hypothesis) rejected (Table 02).

Table 01: Values for the independent variables of composite runs

Sample	PFPP%	OPP%	PPP%	Fibre%	Fat%	Ash%	SC %	BD g/ml	WHC ml/g	OHC ml/g	L*	a*	b*
1	60.00	15.00	25.00	24.74	2.10	5.19	6.61	0.43	12.00	4.00	81.07	3.48	21.775
2	60.00	20.00	20.00	27.44	2.93	5.76	7.05	0.40	16.00	6.00	79.54	3.99	22.23
3	60.00	16.66	23.33	26.92	3.20	5.66	7.35	0.42	9.07	8.00	79.82	3.81	21.85
4	70.00	10.00	20.00	27.19	2.85	5.74	6.82	0.41	12.00	4.00	82.10	3.28	22.83
5	61.66	11.66	26.66	26.84	3.19	5.70	6.23	0.43	12.00	4.40	80.25	3.29	22.67
6	60.00	20.00	20.00	27.44	2.93	5.76	7.05	0.40	16.00	6.00	79.54	3.99	22.23
7	60.00	10.00	30.00	20.23	2.45	5.77	8.44	0.41	15.80	5.58	77.12	3.82	23.12
8	65.00	10,00	25,00	25.91	2.20	5.65	7.50	0.41	12.00	8.80	81.27	3.67	22.36
9	63.33	13.33	23.33	26.92	2.72	5.72	5.89	0.41	16.00	6.38	80.71	3.68	22.59
10	65.00	15.00	20.00	26.58	2.82	5.68	6.99	0.41	10.00	19.07	82.24	3.40	22.38
11	66.66	13.33	20.00	27.20	5.78	5.78	6.70	0.42	9.01	10.00	80.35	3.02	22.60
12	70.00	10.00	20.00	27.19	2.85	5.74	6.82	0.41	12.00	4.00	82.10	3.28	22.83
13	60.00	10.00	30.00	20.23	2.45	5.77	8.44	0.41	15.80	5.58	77.12	3.82	23.12
14	65.00	10.00	25.00	25.91	2.20	5.65	7.50	0.41	12.00	8.80	81.27	3.67	22.36
15	60.00	10.00	30.00	20.23	2.45	5.77	8.44	0.41	15.80	5.58	77.12	3.82	23.12
16	63.333	16.66	20.00	27.68	3.18	5.92	5.58	0.41	9.43	7.00	80.11	3.52	22.34

**BD= Bulk Density, SC= Swelling Capacity, WHC=Water holding capacity, OHC=Oil holding capacity*

Table 02: The summary of the ANOVA for the analyses

Dependent Variable	Model F value	Model (level of significance)	p-value ($p \leq 0.05$)	R^2 value	Adj. R^2 value
Fibre	158.84	Cubic ($p \leq 0.0001$)	Linear mixture, AC, BC, AC(A-C), BC(B-C)	0.9958	0.9896
Fat	195.50	Cubic ($p \leq 0.0001$)	Linear mixture, AC, BC, ABC, AB (A-B), AC (A-C), BC (B-C)	0.9915	0.9966
Ash	10.71	Cubic ($p \leq 0.046$)	Linear mixture, BC,ABC,AC(A-C), BC (B-C)	0.9414	0.8535
SC	12.50	Cubic ($p \leq 0.003$)	Linear mixture, BC, AB (A-B)	0.9494	0.8734
BD	107.87	Quadratic ($P > 0.9275$)	Linear mixture, AB, BC	0.6118	0.4177
WHC	62.03	Cubic ($p \leq 0.0001$)	Linear mixture, AB,AC,BC,ABC,AC (A-C), BC(B-C)	0.9894	0.9734
OHC	2.19	Quadratic ($P > 0.1358$)	Linear mixture, AB	0.5232	0.2848
L*	39.81	Quadratic ($P < 0.0001$)	Linear mixture, AC, BC	0.9049	0.8574
a*	1.18	Cubic ($P < 0.0001$)	Linear Mixture, AB, BC, ABC, AB(A-B), AC(A-C), BC(B-C)	0.9852	0.9629
b*	2.58	Cubic ($P < 0.0001$)	Linear Mixture Components, AB, AC, BC, ABC, AC(A-C), BC(B-C)	0.9982	0.9954

RESULTS AND DISCUSSION

Proximate Composition of Composite Powder Combinations

Fibre content, yoghurts are rich in most macro and micro nutrients but not fibres. Therefore, fibre incorporation is important in nutritional standpoint along with texture formation. Increasing fibre fraction is favourable as nutrient, prebiotic agent, as well as texture modifier in foods. The addition of inulin, pea fibre, and carboxy methyl cellulose, into yoghurts to enhance the texture and rheology also reported (El-Nagar and Brennan, 2001; Meyer *et al.,* 2011).

According to the results, fibre content ranges from 20.23 to 27.68% (Table 01) in different mixtures. When tested individually, fibre contents of orange, passion fruit and pineapple peel powders were 20.14%, 32.85% and 11.66%, respectively (Dias et al, 2020c). The contour plot showed orange peel had the highest contribution for increasing fibre content (Figure 01). The ANOVA showed that the model (cubic) and model terms (Linear mixture, AC, BC, AC(A-C), BC(B-C)) significantly (P≤0.05) affect the fibre content (Table 02).

Fat content: Since the powder will add to fat free yoghurt it is better to have low fat%. Fat content ranged from 2.10% to 3.20% in the mixtures. This is a very low value than fat contents of orange peel (16.20%), but higher than the fat content of pineapple (0.99%) and passion fruit peels (0.47%) (Dias et al, 2020c). The contour plot (Figure 02) showed orange peel largely contributed to the fat content. According to the ANOVA the contribution is significant (Table 02).

Fats from plant origin majorly contain high density lipids, which are healthy. However, milk fat is of animal origin and largely contains unhealthy low density lipids. The amount of fat in the composite powder was also very low. Therefore, they can favourably incorporate into low fat food products.

Ash content: Ash content ranged from 5.19% to 5.92% (Figure 03). The values did not largely deviate from ash contents of orange (4.92%), pineapple (4.56%), and passion fruit peels (6.32%), individually (Dias et al, 2020c). The counter plot showed orange peel was highly responsible for the ash content (Figure 03). According to the ANOVA the contribution was significant (Table 02).

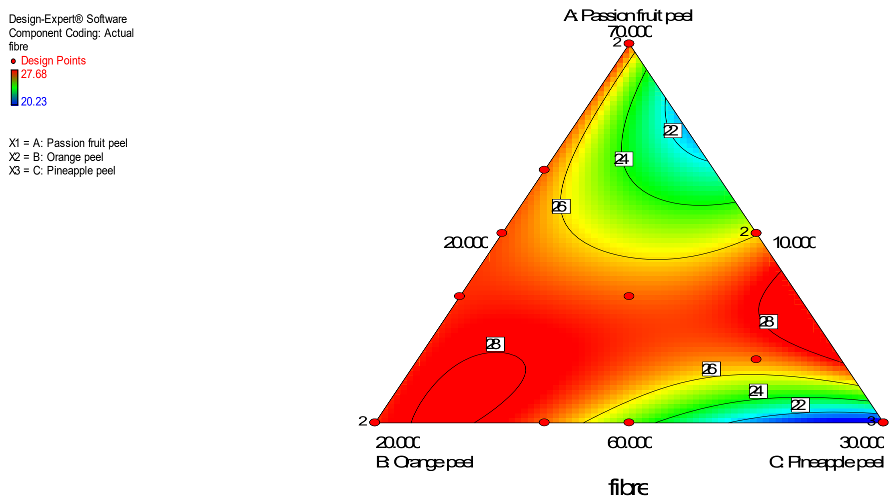

Figure 01: **Contour plot showing the effect of passion fruit (A), orange (B), and pineapple (C) composite peel powders on fibre content (Red colour denotes the highest values while dark blue denotes the lowest values).**

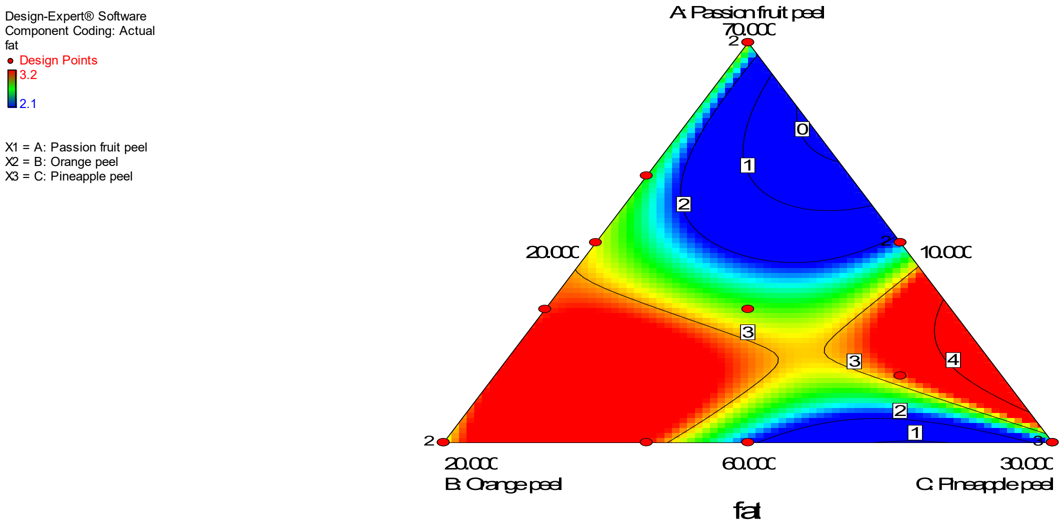

Figure 02: **Contour plot showing the effect of passion fruit (A), orange (B) and pineapple (C) composite peel powders on fat content**

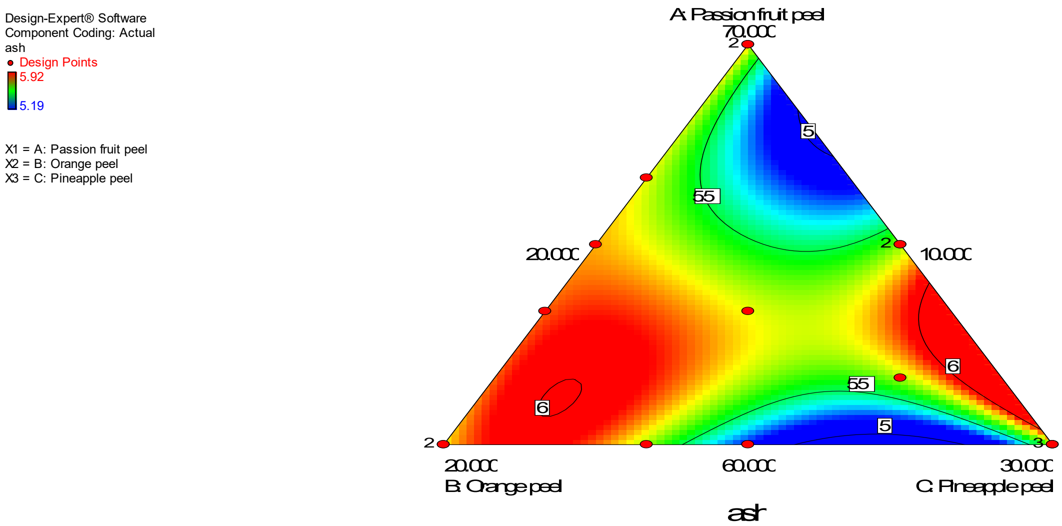

Figure 03: **Contour plot showing the effect of passion fruit (A), orange (B), and pineapple (C) composite peels on ash content**

Physiochemical Properties of Composite Powder Combinations

Yoghurts are white or pale yellow in colour. It is better the additives do not disturb the natural colour of yoghurt, hence consumer preference towards the appearance. Therefore, powder combination having the highest L* and low a* and b* values are most appropriate.

L value,* Passion fruit peels largely contributed to L* values (Figure 04). According to the ANOVA (Table 02), the values were significantly different for model (quadratic) and model terms (AC, BC). The values ranged from 77.12% to 82.26% (Table 01, Figure 04), higher than the L* value of pineapple peel 60.69% (Dias et al, 2020c).

a value,* Orange peels largely contributed to a* values (Figure 05). According to the Table 02, the values were significantly ($p \leq 0.05$) different for model terms, AB, BC, ABC, AB(A-B), AC(A-C) and BC(B-C). The values ranged from 3.02% to 3.98% (Figure 05), and lower than the a* value of orange peel (6.10%) (Dias *et al.,* 2020c).

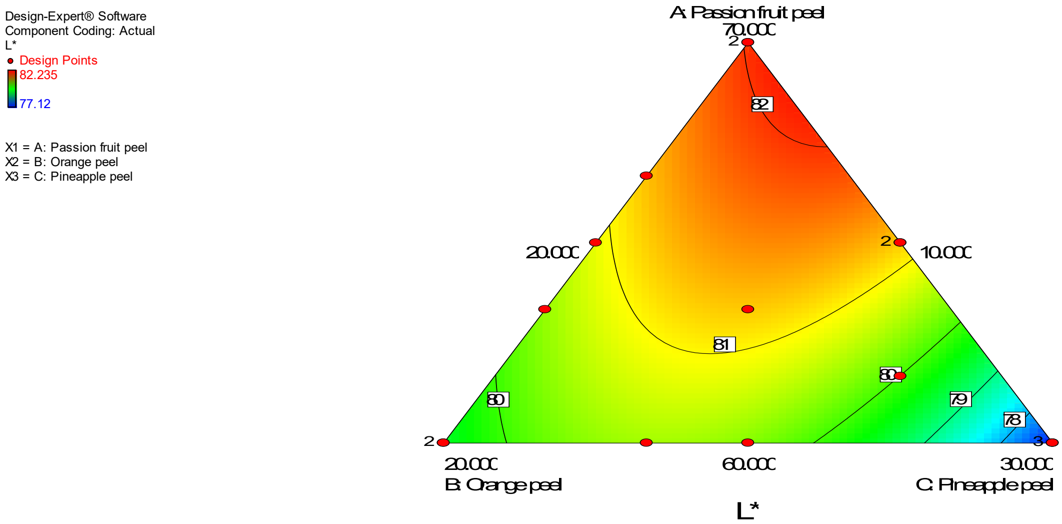

Figure 04: **Contour plot showing the effect of passion fruit(A), orange(B), and pineapple(C) composite peel powders on L* value**

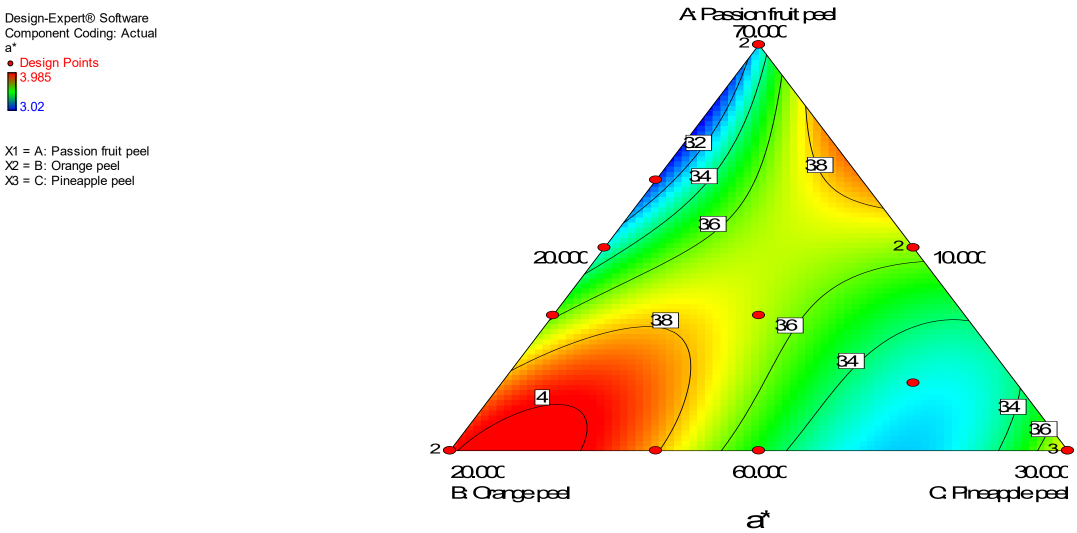

Figure 05: **Contour plot showing the effect of passion fruit (A), orange(B) and pineapple(C) composite peel powders on a* value**

b value,* Pine apple peels majorly contribution to b* values (Figure 06). According to the Table 02, the values have significant ($p \leq 0.05$) effects on the model terms AB, AC, BC, ABC, AC(A-C) and BC(B-C). The values ranged from 21.78% to 23.13%, higher than the a* value of passion fruit peel (15.68%) (Dias et al, 2020c).

Technological Properties of Composite Powder Combinations

Bulk Density and swelling capacity, Bulk Density ranged from 0.40 g/ml to 0.44 g/ml (Table 01). Mixing of fruit peel powders did not significantly ($p > 0.05$) affect the bulk density (Figure 07). The results were proven by model and model terms which were not significant ($P > 0.05$) (Table 02). Swelling Capacity of composite powders ranged from 5.58 ml/g to 8.44 ml/g (Figure 08). The values were less than the individual swelling capacities of passion fruit peel (16.94 ml/g) and orange peel (8.98 ml/g) (Dias et al, 2020c).

Water holding capacity and oil holding capacity, High water holding capacities were favourable in the reduction of whey separation in fat and sugar free yoghurts. However, too much water absorption to fibres can adversely affect the texture and probiotic survival of dairy products.

Water holding capacity values were between 9.01 %/g to 16.00 %/g (Table 01).The addition of passion fruit peel largely contributed to water holding capacity and the effect was significant ($P<0.05$) according to the ANOVA of cubic model (Figure 09 and Table 02). Oil holding capacity was less influenced by mixing fruit peels (Figure 010). Quadratic model and model terms were not significant except model term AB (Table 02).

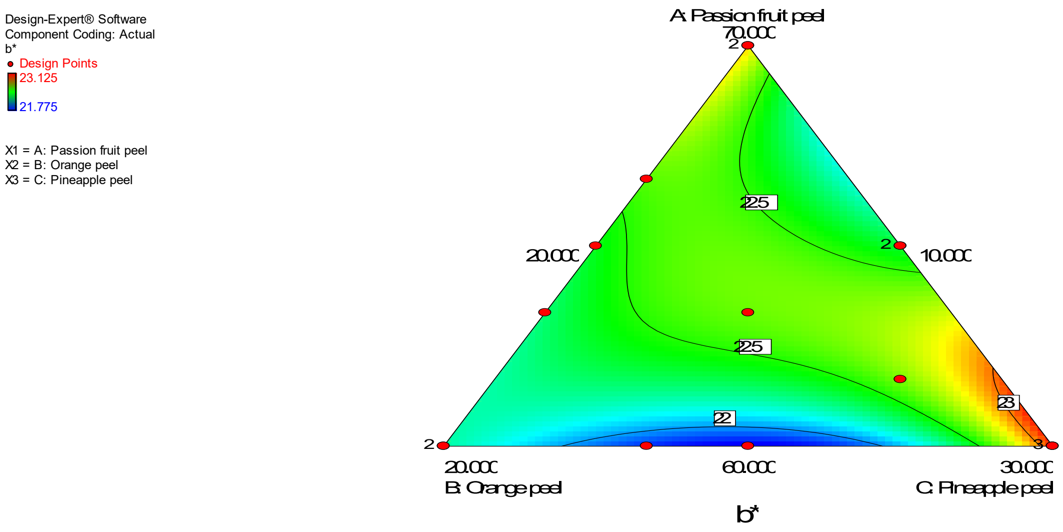

Figure 06: **Contour plot showing the effect of passion fruit (A), orange (B) and pineapple(C) composite peel powders on b* value**

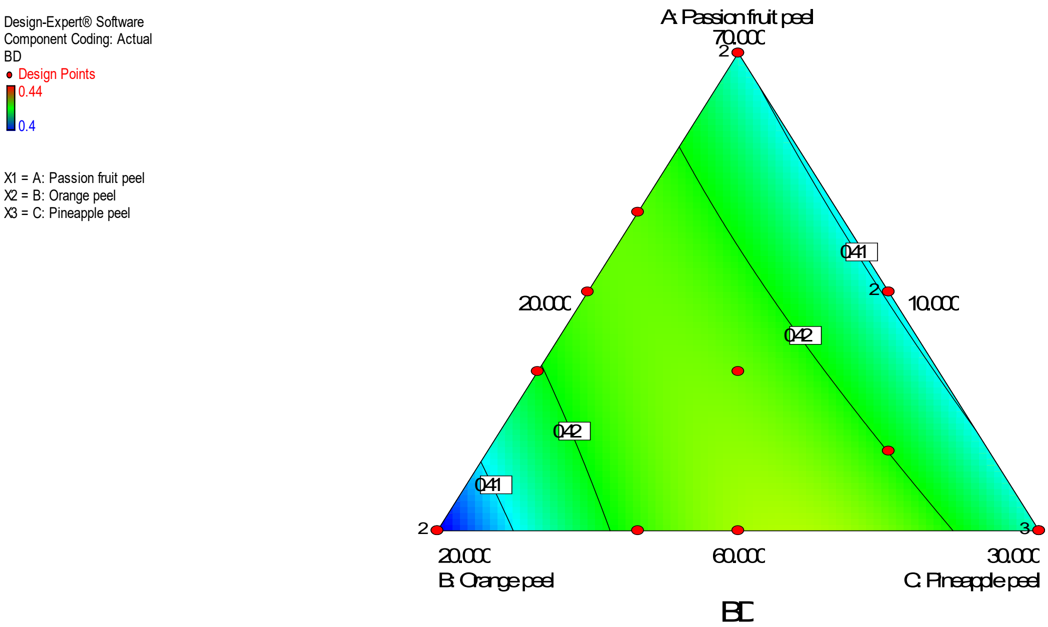

Figure 07: **Contour plot showing the effect of passion fruit (A), orange (B) and pineapple(C) composite peel powders on bulk density**

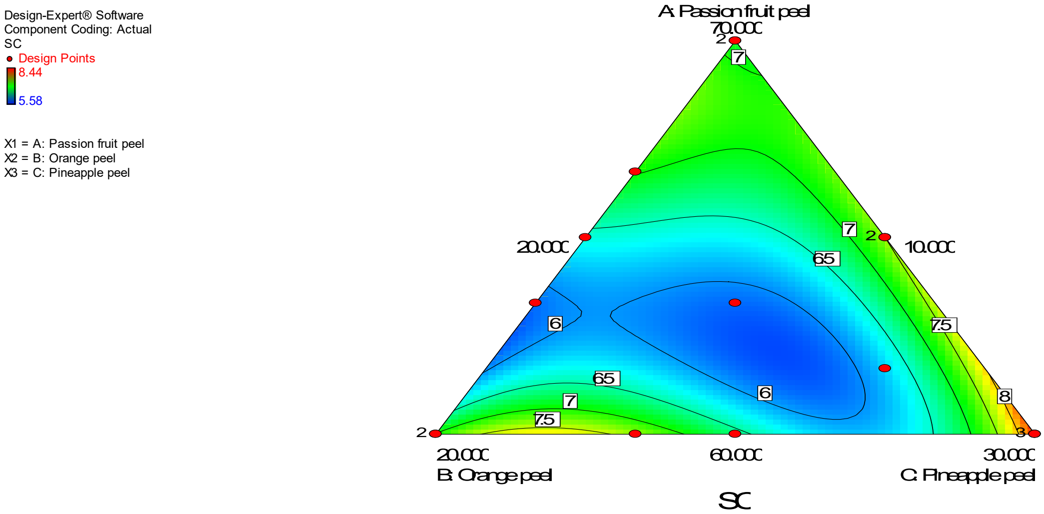

Figure 08: **Contour plot showing the effect of passion fruit(A), orange(B), and pineapple(C) composite peel powders on swelling capacity**

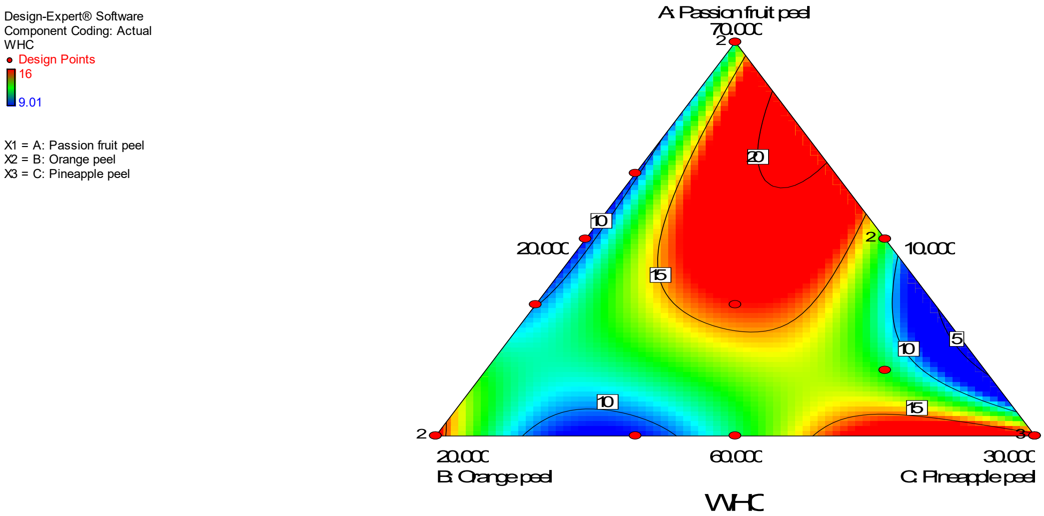

Figure 09: **Contour plot showing the effect of passion fruit (A), orange(B), and pineapple(C) composite peel powders on water holding capacity**

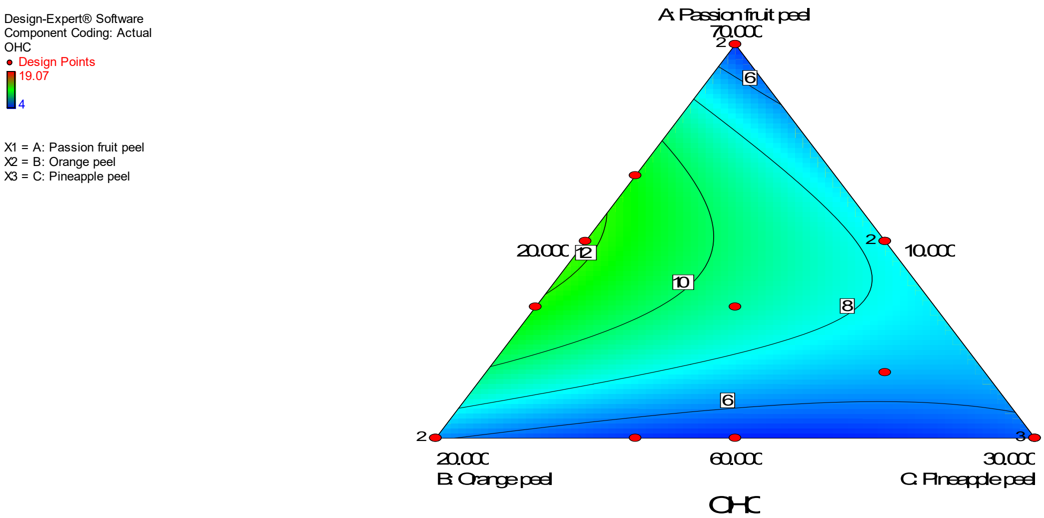

Figure 010: **Contour plot showing the effect of passion fruit(A), orange(B) and pineapple(C) composite peel powders on oil holding capacity**

The closer the R^2 closer to 1.00, the better (Awolu *et al.,* 2016, 2015). Since R^2 value close to 1.00 may also be as a result of an increase in sample numbers, adjusted R^2 values are thereby employed to ascertain the fitness of the curve. So a high adjusted R^2 value is required (Awolu, 2017). In this case, only fibre, fat, ash, SC, WHC and Lab colour values had high adjusted R^2 values that are close to one.

According to Table 01, the highest fibre and water holding capacity were demonstrated by samples 2 and 6. The sample combination was selected for incorporation into fat and sugar free yoghurts. Because, we assumed the two properties can contribute to hold the whey fraction, reduce syneresis and modify texture of yoghurts. The peel combination of the samples is as passion fruit peel, orange peel and pineapple peel were 60%, 20% and 20%, respectively.

Quality attributes of composite peel powder added fat and sugar free set yoghurt was described in a separate paper. Incorporation of 0.5% of fruit peel powder composite reduced whey off by 48.86% ((Dias *et al.,* 2020d).

CONCLUSION

Proximate composition, physiochemical and technological properties of fruit peel powders significantly changed by mixing them in different proportions. The contour plots showed that the orange peel largely contributes to the fibre, fat, ash contents and redness (a*) while passion fruit peels highly contribute to the lightness (L*) and water holding capacity. It is possible to optimise some quality parameters of fruit peel powders by compositing them. However, the manufacturer has to select the optimum mixture based on the end product qualities expected. In the present study, PFPP (60%), OPP (20%), and PPP (20%) were selected as optimum blend due to high fibre content, water holding capacity, and lightness along with less fat content as the composite powder incorporate into fat free yoghurt to reduce its whey off.

ACKNOWLEDGEMENT

This work was fully funded by Sabaragamuwa University of Sri Lanka through the attribution of a research grant [SUSL/RG/2017/05]

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