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Water solubility index and water absorption index of extruded product from rice and carrot blend

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Abstract
Rice flour was added in different proportions (60 - 90%) to dehydrated carrot powder (10-40%). The formulation was extruded at different moisture content (11 -17%), screw speed (200 - 400rpm) and die temperature (120-400°C). The WAI and WSI characteristics were determined as responses. Significant regression models were established with the coefficient of determination, R2 greater than 0.79. The results indicated that moisture content has significant negative influence ($P < 0.08$) on water solubility index and composition and moisture for water absorption index.

Keywords: Carrot, Extrusion, Rice, water solubilty, Water absorption

Introduction
Rice brokens are the by-product of rice milling industry and rice flour prepared out of rice broken can be used as important ingredient for many ready–to-eat breakfast cereals and [5]. Rice contains 7.3% protein, 2.2% fat, 64.3% available carbohydrate, 0.8% fiber and 1.4% ash content [10]. Rice flour has become an attractive ingredient in the extrusion industry due to its bland taste, white color, hypo allergenicity and ease of digestion [7]. The carrot (*Daucus carota*) is a root vegetable, having high dietary fibre content with high water binding capacity (Serena and Knudsen). It is a rich source of beta-carotene and contains, thiamine, riboflavin, vitamin B-complex, minerals [9]. Extrusion cooking is a versatile and efficient method of converting raw materials into finished food products. It can replace many conventional processes in food and feed industry due to its uniqueness, versatility, high productivity, low operating cost, energy efficiency, high quality of resulting products and an improvement in digestibility. Extrusion cooking is widely used in formation of various types of product. However, the incorporation of vegetable in rice based extruded products to make a healthy nutritious snack is still not fully explored.

Material and methods
Widely cultivated paddy variety (Jhelum) obtained from Mountain Research Centre for Field Crops, SKUAST-K, Khudwani. Anantnag was milled at Division of Food Technology, SKUAST-Kashmir, Shalimar using mini rice mill (Model: ASR RM 09). The small rice broken (≤1/8) 0f actual kernel size and carrot (Nantes) from (vegetable science) moisture dried to 12% in rice and in carrot to 6% before grinding were ground to fineness that passes through 200μm sieve and stored under ambient conditions in high density polyethylene (HDPE) for further use.

Extrusion process
The extrusion experiment was performed in a co-rotating intermeshing twin screw extruder (ClexBC-21, Firminy, France) at department of food technology SKUAST -Kashmir. The barrel diameter and its length to breadth ratio were 2.5mm and 16:1 respectively. The extruder barrel is divided in to four zones. Temperature of first second and the third zone was varied was maintained at 30,60,90 respectively, through the experiment, while the temperature at the fourth zone was varied to the experimental design. The extruder was equipped with a torque indicator, which showed per cent of torque in propertion tobe current drawn by the drive motor. Blended materials were ten metered in to the extruder with a single screw volmetric feeder (DSandM, Modena Italy). The feed rate was varied for the optimum filling of the extruder barrel corresponding to screw speed The moisture content of the feed was adjusted dy injecting water (approximately 30℃) in to the extruder with a pump.

Determination of water absorption index and water solubility index

Water absorption index

Water absorption index of the snack was determined by method outlined by Anderson and Griffin [1]. The water absorption index (WAI) measures the volume occupied by the granule or starch polymer after swelling in excess of water. The ground extrudates were suspended in distilled watervat room temperature for 30 minutes, gently stirred during this period and then centrifuge at 3000 rpm for 15 minutes. The supernatant liquid was poured carefully in to tared evoporating dish. The remaining gel was weighed and WAI was calculated as grams of gel obtained per gram of solid.

$$WAI = \frac{\text{weight of sediment}}{\text{Weight of dry solid}}$$

Water solubility index

Water solubility index determines the amount of polysaccharides or polysaccharide release from the granule on the addition of excess of water.WSI was the weight of dry solids in the supernatant from the water absorption index test [1] expressed as percentage of the original weight of the sample

$$\text{WSI (\%) } WSI = \frac{\text{Weight of dissolved solid in supernatant}}{\text{Weight of dry solids}} \times 100$$

Experimental design

The central composit ratatable design (CCRD) for the four independent variables was performed. The independent variables considered were composition i.e Rice flour: Carrot flour (A), moisture (B), screw speed (C) and Barrel temperature (D). The independent variables and variation levels are given below in Table 1.

Response surface methodology was applied for experimental data.

The results were analysed by a multiple regression model which describes the effects of variables in the models derived. Experimental data were fitted to the selected models and regression coefficients were obtained. The Analysis of Variance (ANOVA) tables were generated for each of the response functions. The individual effect of each variable and also the effects of interaction term in coded levels of variables were determined. Responses obtained as a result of the proposed experimental design were subjected to regression analysis in order to assess the effect of composition, moisture content, screw speed and barrel temperature on product characteristics. Second order polynomial regression models were established for the dependent variables to fit experimental data for each response using statistical software Design -Expert 10 [8].

Table 1: Effect of processing condition on WSI and WAI

composition	Moisture (%)	Screw speed(rpm)	Barrel temperature (°C)	WSI (%)	WAI(g)
20	17	200	140	3	2.33
20	17	250	120	2.76	2.4
20	17	250	160	5.1	2.42
20	17	250	160	3.4	2.43
20	17	250	120	3.5	2.43
20	11	250	120	3	2.44
30	14	250	160	3.5	2.44
20	17	250	160	5.2	2.45
30	14	250	120	4.4	2.45
10	14	300	140	3.6	2.45
20	17	300	140	3.7	2.45
10	20	300	140	3.8	2.46
10	20	300	180	3.6	2.46
20	23	300	140	3.8	2.47
40	17	300	140	2.86	2.47
20	17	300	140	3.2	2.48
10	20	300	140	4.8	2.48
20	17	300	140	2.87	2.48
10	14	300	100	3.4	2.48
10	14	300	140	4	2.49
30	20	300	140	2.83	2.49
10	20	350	120	2.49	2.51
30	20	350	160	3.2	2.51
0	17	350	120	3	2.51
20	17	350	120	3.6	2.52
30	14	350	160	3.5	2.52
30	14	350	160	5.1	2.56
30	20	350	120	5.3	2.57
30	20	350	160	5.1	2.68
10	14	400	140	3.5	2.69
20	17	200	140	3	2.33

Results and discussion

Effect of processing of processing on water solubility index

WSI measures the amount of soluble components released from the starch after extrusion. High WSI is an indicator of good starch digestibility as it implies the extent of gelatinization and dextrinization. The model obtained for the

WSI is given below

Quadratic Model Equation for Water solubility Index

$$WSI=3.28+0.16A-0.20B+0.060C+0.27D+0.37AB+0.03AC-0.08AD+0.06BC-0.6BD-0.064CD+0.32A^2+0.093B^2+0.030C^2+0.093D^2 \quad ......(1)$$

It was observed from Equation that the coefficient of B is negative, but that of *A*, *C* and *D* are positive. Therefore, increase in moisture content may reduce the water solubility index, whereas increase in Composition, screw speed and temperature may increase the water solubility index of the product

Table 2: ANOVA for WSI and WAI.

Regression	WSI (%)	WA I(g/g)
R-squared	0.7901	0.9253
Adj-R^2	0.5942	0.8860
Pred-R^2	0.0357	0.8310
Adeq-pression	6.877	22.708
C.V%	14.05	0.98
Lack of fit	N.S	N.S

Water solubility index (%) of Extrudates ranged from 2.76 to 5.1% (Table 1) The ANOVA (Table. 2) and response surface plots (fig1a) showed the significant negative linear influence of moisture while significant positive linear influence of carrot incorporation ss and BT. It is evident from Figure 1a that water solubility index increased quadratically with the increase in carrot incorporation, which may be due to increase in fibrous content in the feed formulation. The water solubility index increased initially with the increase in moisture content, which may be due to proper gelatinization and lateral expansion of the starch, whereas further decrease with the increase in moisture content may be attributed to reduction in lateral expansion due to plasticization of meltas observed by Ding *et al* [3]. There was a slight decrease with the increase in screw speed (Figure 1b),which may be because of high mechanical shear exerted on Extrudates, whereas further decrease in water soluble index with the increase in screw speed may be the result of higher expansion of the product. Water solubility index decreased initially and increased further with increase in temperature, which may be attributed to the similar variation of lateral expansion of the Extrudates with increase in temperature.

Effect of processing conditions on water absorption index

The water solubility of Extrudates was found in the range of 2.33 to 2.69g/g. The quadratic model for WAI is: +2.48-4.167E-00A-5.417E-003B-917E-003C+9.583E-003D-0.033AB-0.024AC-0.048AD+0.027BC+0.061 BD+6.875E-003CD

The regression showed that the WAI decreases with increase in composition and moisture content and screw speed and increases with increase in barrel temperature. The ANOVA Table 2 and the response surface plots depicted in fig 2a shows the effect of process variables on WAI. It was observed from Figure 2b that increase in Carrot preperation resulted in quadratic decrease in water absorption index. Altan *et al.* [2] also reported the similar behaviour due to competition of absorption of water between pomace and available starch. Water absorption index decreased with increase in moisture content, which may be attributed to the reduction of elasticity of dough through plasticization of melt at higher moisture content [4]. It can be seen from Figure 2b that water absorption index increased screw speed and may be attributed to high mechanical shear and higher expansion due to gelatinization. Water absorption index increased with the increase in increase in temperature probably due to increased dextrinization of at higher temperature [6].

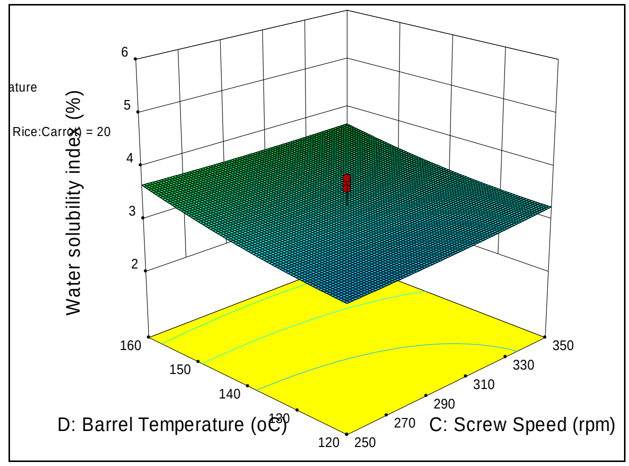

Fig 1a: Effect of Screw speed, Barrel temperature and Moisture content on WSI

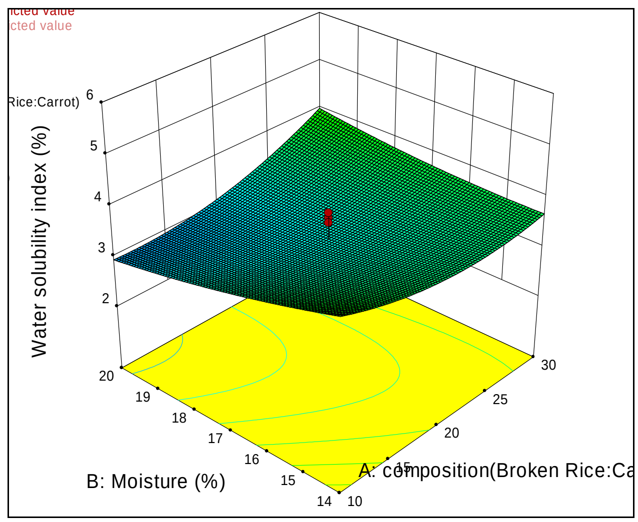

Fig 1b: Effect of composition and moisture on WSI

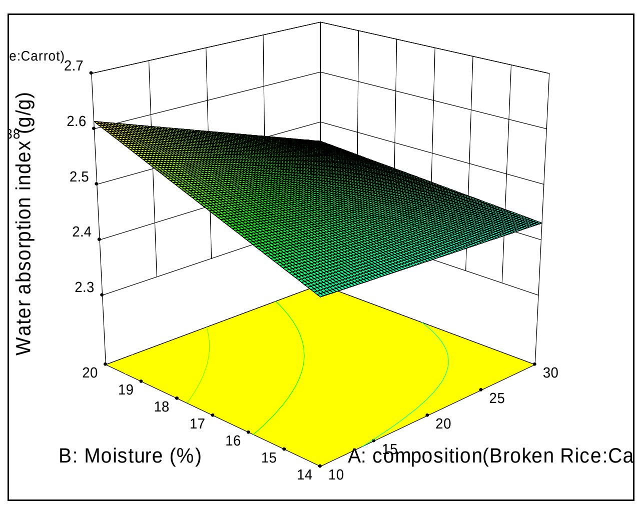

Fig 2a: Effect of Composition and Moisture content on WAI

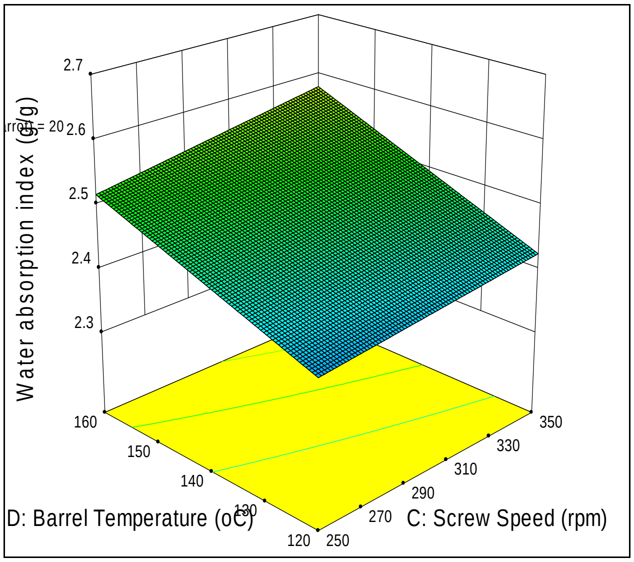

Fig 2b: Effect of Barrel temperature and screw speed on WAI

Conclusion

Response surface methodology was applied to experimental data in order to assess the effect of extrusion parameters. The results were analysed by multiple regression method which describes the effect of variables in the models derived. Graphical techniques in connection with RSM will help in locating operating conditions.

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