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OPTIMIZATION OF POTATO FLOUR BASED COMPLEMENTARY FOOD USING D-OPTIMAL DESIGN

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Abstract

The huge demand of nutritious, calorie dense, non allergenic and cost effective complementary food is continuously increasing so as to curb the prevalence of malnutrition among children especially in developing countries having limited resources. Therefore, it becomes essential that the synergistic effects of the primary constituents should be exploited to yield maximum optimal functional properties. This study was carried out to develop a weaning mix by using Rice flour (A), Potato Flour (B) and Chickpea Protein Isolates (C) to obtain a formulation having optimal physicochemical properties (Water Absorption capacity, Water Solubility Index, Texture) and sensorial properties by Optimal Mixture Model Design of response Surface Methodology. The lower limit (Rice flour- 50; Potato flour- 20 and Protein isolate-5) and upper limit (Rice flour- 70; Potato flour-30 and Chickpea Protein isolate-10) for each mixture component was used. Experimental designs had 16 experimental runs with physicochemical and sensorial properties as their responses. The constraint fixed for optimization of the weaning mix was to maximize the overall acceptability and keeping the physicochemical properties WAC, WSI and texture within range. Within these constraints, d optimal design selected the variation 65A:28.1B:6.9C as the most desirable one. The predicted and observed values of the analyzed responses of the optimized formula were compared ($p<0.05$) and the results were found to be in good agreement with the predicted values.

1.Introduction

Complementary feeding period is the period when the diet of older infants (age when toddlers are 18 to 24 months old) and young children (age between 24 months and 5 years old) is transitioned from exclusive breast feeding towards eating the family diet. Infants are able to maintain adequate growth until the age of six months thereafter when additional nutrients are required to complement breastfeeding (Tiwari et al, 2016). WHO has postulated that complementary feeding in the first 6 months along with breastfeeding as one of the potential action to address the issue of malnutrition in lower and middle income countries (WHO, 2017). The most essential characteristics of weaning food or infant formula is to be rich in calories, easily digestible good quality protein content, along with sufficient vitamins and minerals. It should form semisolid soft slurry when mixed with warm or cold water (IAP, 2021).

Traditional Indian processing technologies have pioneered the preparation of weaning food by using different combinations of diverse food components, especially cereals and starches. Cereals like wheat, maize, rice, oats etc. along with legume flours have been used in preparation of weaning mixes that are similar in appearance to conventional food and also have an added advantage of aiding physiological functions along with providing adequate nutrition (Das et al, 2012). All the above mentioned formula basically contain a single dominant cereal, pulse or fruit as a key ingredient due to which various kinds of mixes have to be administered regularly so as to provide complete balanced nutrients to the child. However, due to large numbers of working mothers and nuclear family settings, there is a huge demand for safe, organic and ready-to-serve weaning food and has ever-growing market (Misra & Dwivedi, 2015).

Qualifying the above-mentioned criteria, ingredients like potato flour, rice flour and chickpea protein isolates have been exploited for their potential of being developed as a cost effective and wholesome weaning mix. Potato flour is an inexpensive, nutritious and an excellent source of carbohydrates. Research involving the development of integrated process for the production of shelf stable potato flour and further baked products mixed with wheat flour should be initiated in order to diversify the use of potato as well as to enhance nutritional quality of products since the quality of protein in potato is the best among other plants protein (Mirajkar et al, 2013). Among several processed products, potato flour is the oldest commercial potato product, which can be stored safely and incorporated into various recipes.

Chickpea possesses good balance of amino acids, non-allergenic highly bioavailable protein and relatively low level of antinutritional factors than soybean. It is a good source of high-quality protein, carbohydrates, vitamins (thiamine and niacin), minerals (calcium, phosphorous, iron, magnesium, and potassium) and its oil is rich with the essential fatty acid. Therefore, it is considered as a suitable source of dietary proteins (Wang et al, 2010). Chickpea protein isolates have been used to increase the protein content of the mix as the protein efficiency ratio (PER), net protein retention (NPR) and net protein utilization (NPU) of chickpea based infant formula were not different to soy or milk based formula. The mean percentage of absorption, retention and biological value of the chickpea formula were 72.4, 26.4 and 35.1 compared to that of soy 69.6, 24.3 and 34.0, respectively (Malunga et al, 2014) which makes it a better choice.

The general acceptability of weaning foods by infants is greatly influenced by the functionality of the ingredients used for their production. Indeed, the functionality of a food is an interactive outcome of the food ingredients in addition to its nutritional value, which has a great impact on its utilization (Kinsella & Melachouris, 1976). Functional properties such as gelation, water holding capacity, viscosity and pasting properties are very important for ensuring the appropriateness of the diet to the growing child. The consistency and energy density (energy per unit volume) of the complementary diet coupled with frequency of feeding are also important factors in determining the extent to which an infant can meet his energy and nutrient requirements (Kikafunda et al, 1997). In the processing of most complementary foods, emphasis is usually on the nutritional quality and quantity of the ingredients rather than their functional properties (Bookwalter et al, 1987).

For example: In a 3 component system:

Where in = 1,2,3 $\quad 0 \leq x_i \geq 1$

$$x_1+x_2+x_3=1 \qquad (1)$$

The mixture design statistical method is the most suitable method used in optimizing the production process of a complementary food. The mixture design method is usually used in mixture formulation whose sum of all components must be equal to 100 (Brereton, 2003).

There are many types of mixture model design but D-optimal design is constructed to minimize the overall variance of the predicted regression coefficient by maximizing the value of determinant of the information matrix (Esbensen et al, 2014). The experimental region is not simplex but it is irregular (Valko, 2000). As compared with other traditional designs, the benefit of D-optimal configuration is that, it works on straight optimization focussing a chosen optimality criterion along with the suitable model. It has a smaller number of runs and thus carries low cost of experimentation. Furthermore, combined mixture and process variables can be used in the same experimental design (Valko, 2014).

2. Materials and methods

2.1.Procurement of Raw Material

The processing cultivar of potato "Kufri Chipsona1" was procured from Central Potato Research Institute Campus, Modipuram, Meerut. Kufri Chipsona 1 was used for the preparation of flour due to its low reducing sugar and high starch content. Other ingredients were purchased from local market. All the chemicals used in the study were of analytical grade obtained from Merck-Sigma.

2.2.Experimental designs for the development of Weaning mix formulation:

An optimal mixture model design was used with arbitrary lower and upper bounds as explained by (Esbensen et al, 2014). The three independent variables were Rice flour (A), potato flour (B) and Protein isolates (C). The lower limit (Rice flour- 50; Potato flour- 20 and Protein isolate-5) and upper limit (Rice flour-70; Potato flour- 30 and Protein isolate-10) for each mixture component was worked out for selecting runs of these variables. The design produced 16 experimental formulations (Table 1).

Table 1. Actual and Predicted value of WSI, WAC, Texture and Overall acceptability of the Optimal Mixture Design

RUNS	Rice Flour (A)	Potato Flour (B)	Protein isolate (C)	Actual WAC	Predicted WAC	RSE %	Actual WSI	Predicted WSI	RSE %	Actual Texture	Predicted Texture	RSE %	Actual Overall acceptability	Predicted Overall acceptability	RSE %
F1	62.5	30	7.5	8.90	9.25	3.7429	31.00	32.47	4.5274	8.10	8.21	1.3793	8.30	8.43	1.5094
F2	68.125	23.125	8.75	8.80	8.11	7.8557	27.00	24.72	8.444	8.60	8.26	3.9534	8.50	8.48	0.2639
F3	65	25	10	8.00	8.27	3.2778	29.00	26.19	10.7264	8.70	8.63	0.8471	8.50	8.64	1.6091
F4	65	25	10	8.10	8.27	2.0688	25.00	26.19	4.5462	8.50	8.63	1.4712	8.70	8.64	0.7059
F5	65	30	5	9.10	9.06	0.3866	36.00	34.79	3.4884	8.70	8.67	0.3079	9.00	8.93	0.8385
F6	70	25	5	7.70	7.74	0.4904	24.00	25.66	6.4748	8.20	8.29	1.0854	8.20	8.21	0.1773
F7	63.125	28.125	8.75	8.90	8.91	0.1134	24.00	29.42	18.4172	7.90	8.39	5.8779	8.60	8.47	1.5865
F8	70	20	10	7.00	7.13	1.7942	21.00	21.93	4.2613	7.70	7.77	0.8568	8.10	8.10	0.0242
F9	70	25	5	7.70	7.74	0.4904	24.00	25.66	6.4748	8.20	8.29	1.0854	8.20	8.21	0.1773
F10	70	20	10	7.20	7.13	1.0117	20.00	21.93	8.8203	7.70	7.77	0.8568	8.10	8.10	0.0242
F11	60	30	10	8.70	8.38	3.8158	30.00	28.37	5.7520	8.00	7.88	1.5587	7.60	7.59	0.0989
F12	65	30	5	9.20	9.06	1.4897	37.00	34.79	6.3631	8.80	8.67	1.4608	8.90	8.93	0.2819
F13	65.625	28.125	6.25	9.00	9.02	0.2672	30.00	31.32	4.2282	8.60	8.58	0.2453	8.80	8.80	0.0292
F14	60	30	10	8.30	8.38	0.9573	29.00	28.37	2.2270	8.00	7.88	1.5587	7.60	7.59	0.0989
F15	68.125	24.375	7.5	8.60	8.37	2.8027	27.00	25.97	3.9812	8.60	8.31	3.5375	8.50	8.50	0.0534
F16	70	22.5	7.5	7.40	7.78	5.1351	27.00	23.21	14.0370	7.80	7.88	1.0691	8.10	8.08	0.1999

2.3.Preparation of Potato Powder

The selected potatoes were washed, peeled, shredded and blanched in boiling water at 100±°C for 5 min. After blanching, the shredded potatoes were dried in cabinet tray drier (VAM 934, VAM Instrument Pvt. Ltd., India) for 6 to 8 h at 70°C. The dried potato shreds were ground in a high speed mixer (Inalsa) and sieved through 70 mesh sieve to separate potato powder and potato grits. The potato powder was then packed in laminated LDPE bags, sealed and stored at ambient temperature, until further use.

2.4.Preparation of Chickpea Protein Isolate

Chickpea isolates were prepared from the *desi* cultivar (K-850) by methods given by Mao and Hua (2012) with slight modifications. Chickpea flour was defatted with water in the ratio of (1:20) with the pH adjusted to 10 using 1M NaOH. The slurry was heated at 40º C in water bath for an hour with manual stirring at every 5 minutes. It was centrifuged and the supernatant was collected with a continuous pH adjustment at 4.5 with 1M HCl. Precipitation of protein isolates was done for about an hour, followed by washing and neutralization of isolates which were then vacuum dried at 40º C for 8 hours at 550 mmHg and finally collected and stored in an air tight container till future use.

2.5.Water absorption capacity and Water Solubility Index of Weaning Mix

The water absorption capacity (WAC) measures the volume occupied by the granule or starch polymer after swelling in excess of water and water solubility index (WSI) determines the amount of free polysaccharide or polysaccharide release from the granule on addition of excess water. WAI and WSI were determined according to the method developed for cereals (Yagci & Goguş, 2008; Chandra et al, 2015). The potato powder and optimized product were suspended in water at room temperature for 30 min, gently stirred during this period, and then centrifuged at 3,000× g for 15 min. The supernatants were decanted into an evaporating dish of known weight. The WAC was the weight of gel obtained after removal of the supernatant per unit weight of original dry solids. The WSI was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample.

2.6.Texture Analysis and sensory analysis

Consistency of the snacks was examined by TA-XT 2i Texture Analyzer (Stable Microsystems, Surrey, U.K.). The sensory evaluation for color, flavor, taste, texture, crunchiness and overall acceptability was also done on the basis of nine point hedonic scale by a group of thirty semi trained panelists with five replications.

2.7. Statistical Analysis:

The utility of using mixture design is to ascertain the response changes as a function of the relative proportion of components being used in the product optimization. Optimal design is used when the component ranges are used in different proportions having multi-component constraints where the best estimates were provided algorithmically by the chosen model. D Optimal algorithm chooses the best run that has minimum variance –co-variance matrix to the process by creating fractional general factorial experiments. The statistical parameters including the adjusted multiple co-relation co-efficient (R^2), co-efficient of variation (CV%), lack of fit, regression (p value) and regression (F value) were used to evaluate the best fitting mathematical model. The design was expressed by polynomial regression equation to generate the model as follows:

Where

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x2 + \beta_3 x3 + \beta_4 x_4 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{44} x_4^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{14} x_1 x_4 + \beta_{23} x_2 x_3 + \beta_{24} x_2 x_4 + \beta_{34} x_3 x_4 \quad (2)$$

Where Y_i, is the predicted response and β_0, β_1 and β Where Yi, is the predicted response and 0, 1 and 2 are linear co-efficient, quadratic co-efficient and interaction co-efficient respectively. The suitable polynomial equation for the design such as linear, quadratic or cubic was chosen according to the fittest model suggested algorithmically. To facilitate better understanding of the response variables and perceive their interaction between the response and causal factor variables, the mixture design space and three dimensional (3D) contour plots of the fittest polynomial regression were generated.

The three independent factors studied were Rice flour (A), Potato flour (B) and Protein Isolates (C). The responses studied were: Y_1 is Water absorption capacity (WAC), Y_2 is Water Solubility Index (WSI), Y_3 is Texture and Y_4 is Overall acceptability (OA).

The Data was subjected to statistical analysis using response surface methodology (Design Expert version 10.0 by Statease Inc.) Selection of a predictive model to accurately describe each response was based on the quality of fit evaluated by analysis of variance

(ANOVA) statistical package on a predefined level of significance of 0.05.

2.8.Optimum ingredients formulation for the weaning mix

The optimization was done by the numerical and graphical methodology. The constraints for optimization were maximizing the overall acceptability and potato flour content; at the same time keeping the Protein Isolates, Water Absorption Capacity (WAC), Water Solubility Index (WSI) and texture in range. The goal of the constraints was to finalize a low cost infant formula having optimal physicochemical properties. The predictive regression models developed for each of the criteria were used to develop ternary contour plots to display the effects of the ingredients on the properties. By superimposing the contour plots of all the selected criteria for an optimal weaning mix the optimum region was determined by generating the overlay contour plot for the optimization criteria. From the selected optimum region obtained, the optimal infant formula variation was selected. Thus, the chosen blend was reformulated and varied in treatment. During the physicochemical analysis; the samples were stored at a controlled temperature of 25±2º C in High density Polyethylene (HDPE) sealed packets. Sensory evaluation of the mix was carried out using a nine point hedonic rating scale. The sensory was done by a panel of thirty semi trained evaluators.

3. Results and discussions

Table No. 1 shows that there were 16 formulations in the physical tests analysis. The actual and predicted data sets of the physical tests are tabulated in Table 2.

Table 2. Predicted and observed values for optimized formulation (65PF:28.1RF:6.9PI)

Responses	Predicted values	Observed values	RSE %
Overall Acceptability	8.74814	8.667	0.2172
Water absorption capacity (WAC)	8.98187	8.8667	1.2816
Water Solubility Index (WSI)	35.3619	34.268	3.0386
Texture	8.41681	8.33	1.0313

Table 3. ANOVA table for WSI, WAC, Texture and Overall acceptability

	WAC Y_1	WSI Y_2	Texture Y_3	Overall acceptability Y_4
Model	Significant	Significant	Significant	Significant
R^2	0.9850	0.9644	0.9813	0.9748
Adjusted R^2	0.9626	0.9122	0.9783	0.9617
Predicted R^2	0.9681	0.7122	0.9119	0.9363
p value	0.0001	0.0011	0.001	0.0001
F value	43.88	18.32	76.17	76.34
CV %	1.69	3.76	0.701	0.9636
Lack of fit	Not Significant	Not Significant	Not Significant	Not Significant
Standard deviation	0.1403	1.19	0.059	0.0865
PRESS	15.53	69.82	0.2041	0.1618

3.1.Effect of variables on Water Absorption Capacity (WAC) Y_1: The software suggested the cubic model as the model to describe the effect of components on the WAC having significant model where lack of fit is insignificant (Table 3). The water absorption capacity of the formulations ranged from 7.2 to 9.2. ANOVA revealed the model's F value as 43.88; implying that the model is significant at $p < 0.0001$ level. The predictive model could explain 98.5% of the influence of variations composition on the WAC of the blends (Table 3) as elaborated in equation No. 2.

3.2.Water Absorption Capacity (WAC)

$$Y_1=8.477144A+7.135004B+8.84316C+1.636376AB+1.940165AC-1.11189BC \quad (3)$$

Water absorption capacity of flours plays an important role in the food preparation process because it influences other functional and sensory properties. Furthermore, the range of application of flours as food ingredients is dependent, to a large extent, on their interaction with water especially when it comes to development of a complementary food. Potato flour (especially of Kufri Chipsona varieties) has been found to have a very high WAC as compared to the flours of other varieties (Vaishali et al, 2020). Water absorption is a characteristic of the physical and chemical properties of the starch granules, fiber and also protein. The hydrophilic groups bind the water molecules thereby enhancing the gel formation capacity (Hanim et al, 2014). Thus, the enhancement of amylase leaching and solubility along with the loss of crystalline structure increased the WAC.

The protein isolates of *desi* cultivar have been found to have better WAC as compared to *kabuli* cultivar (Kaur & Singh, 2007) which was the primary concern of it as a constituent. It had a positive impact on the WAC of the weaning mix which may be due to the reason that isolates have great ability to swell, dissociate and unfold, exposing additional binding sites which is disrupted by carbohydrate and other flour components present (Kinsella, 1979).Another factor may be that the protein gets dissociated during the production of isolates and thereby increases the water absorbability because of the increase in polar and non polar amino acids occur. The formation of matrices is stabilized by hydrophobic interactions which retains water in their micro structure (Avanza et al, 2012). Kuntz and Brassfield (1971) reported that lower WAC in some flours may be due to less availability of polar amino acids in flours and thus, high WAC warrants better bioavailability of polar amino acids. However, the WAC of proteins follow a different relation when participating in a hydrophilic component system because the selective pH, temperature dependent solubility along with surface hydrophobicity make them to aggregate and form precipitate (Klupšaitė & Juodeikienė, 2015). Thus, in this condition when some component favors the positive effect and the other does not, the cubic equation sums this model to be the best, denoted by cubic equation no.2. In scheffe's model, there are no absolute interactions which mean that apart from the interactions affecting the responses in the model, the individual component is also impacting the response separately which is evident from the nonlinear regression bending (Figure1). Thus, in this model WAC the properties of three components the rice flour, potato flour and protein isolates are affecting the WAC both individually and mutually as exemplified in the equation 2.

3.3.Effect of variables on Water Solubility Index (WSI) Y_2 of the formulated variations of the weaning mix was significantly affected by the interaction between the varying concentration of rice flour followed by potato flour and protein isolates ($p<0.001$). F value of 18.32 denotes the model terms are significant. The effect of the variables on the WSI could be explained as per the cubic model equation No. 3 which could explain 96.44 % of the interaction observed by the variables on the WSI (Table 3).

Water Solubility Index (WSI)

$$Y_2=-29.48898A+20.53575B-63.3744C+8.009893AB+213.9651AC+181.6413BC-336.396ABC-36.7067AB(A-B)-163.913AC(A-C)-71.7725BC(B-C) \quad (4)$$

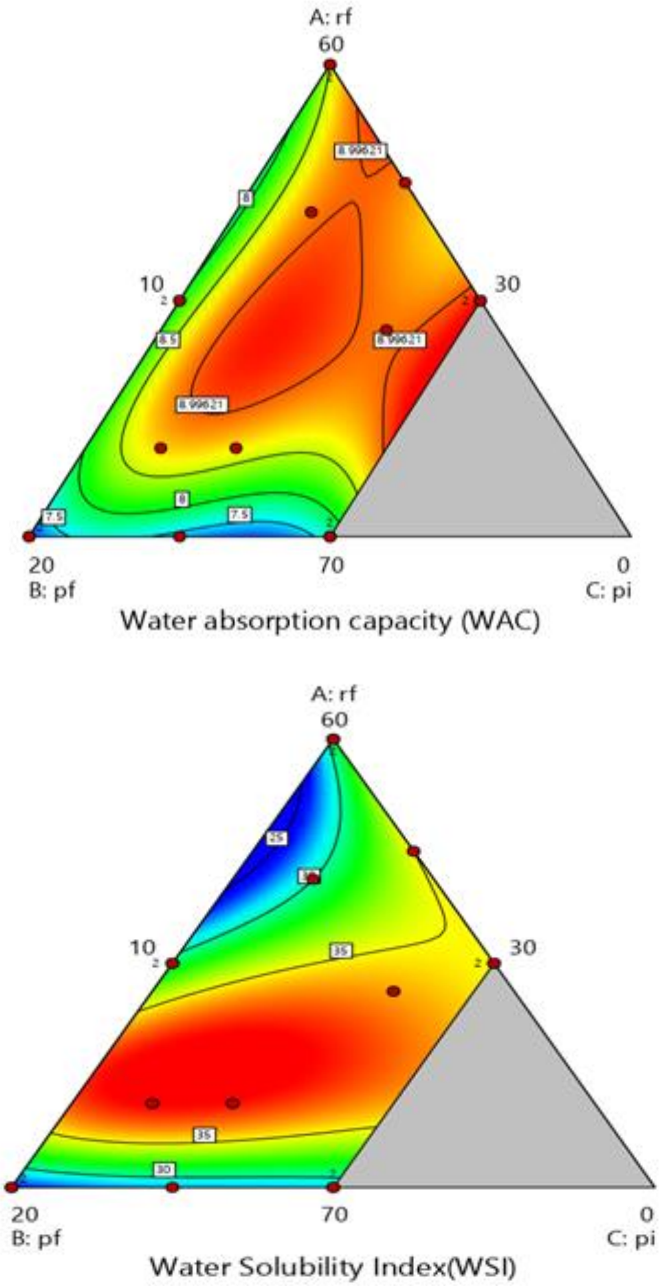

Figure 1. Contour plot illustrating the relationship between component rice flour, potato flour and protein isolates towards the response, (a) Water absorption capacity (WAC) Y_1 (b) Water Solubility Index (WSI) Y_2

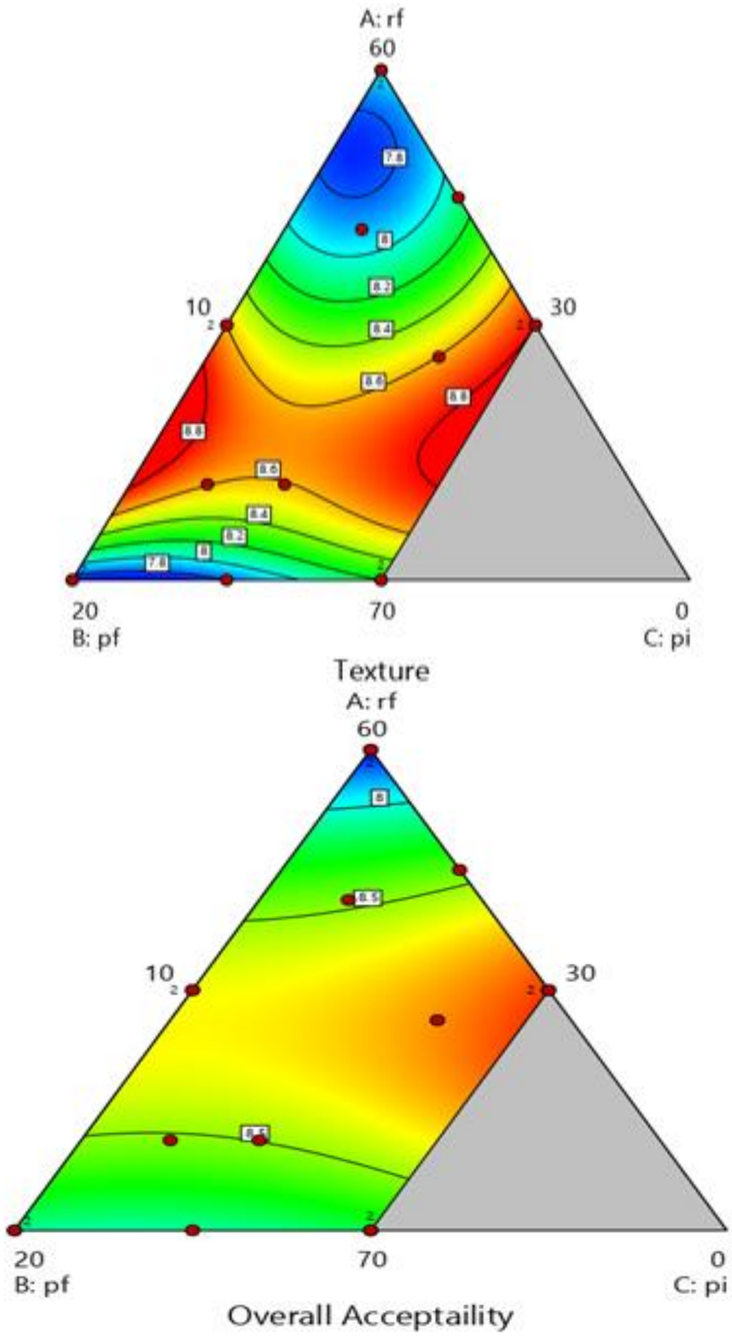

Figure 2. Contour plot illustrating the relationship between component rice flour, potato flour and protein isolates towards the response, (a) Texture Y_3 (b)Overall acceptability Y_4

The effect of A, B and C could be perceived vividly in the contour diagram showing the higher polynomial relation between the components on the response Y_2. 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 present in potato and rice flour, as potato flour has been found predominant in improving the swelling power and in the rice flour blends (Sun & Yoo, 2011). It justifies better pasting properties of potato starch as compared to sweet potato having better gelatinizing property, paste clarity at lower temperature (Nwokoche et al, 2014) making it suitable for supplementing as an infant food.

The higher WAC and WSI values of potato starch may be attributed to a higher content of phosphate groups on amylopectin, which causes repulsion between phosphate groups on adjacent chains and consequently hydration is increased by the weakening of bonds within the crystalline structure (Hoover, 2001). On the contrary, presence of chickpea protein isolate in the component system even in comparative low proportion could definitely alter the resultant effect of the interactions (Figure 1). The solubility of protein isolate is basically affected by the amount of denatured protein and fat present, as both these reduces the solubility and emulsion forming capacity and thus due to this property higher amount of PI in the weaning mix would make it reconstitution difficult.

3.4.Effect of variables on Texture Y_3:

The effect of the flour and protein isolate blend on the texture is exemplified in the equation no. 4. The F value of 58.48 ($p<0.001$) depicts that the variables had 98.18% effect on the texture of the formulations of the weaning mix (Table 3). The positive cubic equation denotes that the texture of the mix followed high polynomial relation due to the combined effects of factors A, B and C.

Texture Y_3= -$-4.34382\ A+40.79805\ B+86.7133\ C-0.694434\ AB-1.32265\ AC-1.57511\ BC+0.0659\ ABC+0.00649\ AB\ (AB)+0.007064\ AC\ (AC)+0.004248\ BC\ (BC)$. (5)

It is an important aspect of a proprietary food especially when it has to be accepted by children so as to provide a sumptuous eating experience along with delectable taste and enhanced nutritional properties. Textural properties are affected by the individual functional properties of the flour used and the interaction between the ingredients while formulating a product.

The 3D contour plot (Figure 2) shows that the texture of the complementary mix was improved as the potato flour was increased till it attained a maximum level of 28; this change could be attributed to the soft and pasting property of potato flour. Optimum WAC and WSI are shown to have a conditioning effect on the texture of the mix. Tuberin is a major protein of potatoes, a non-gluten protein, while wheat flour has gluten in which gliadin and glutenin are entangled to form a three-dimensional network. The crude ash contents of medium flour are 0.5-1.3%, while potato flour contains as high as 1.96~2.48% of ash depending on the variety. Thus, the characteristics of tuberin protein and high ash content not only makes it make it micronutrient adequate but also has a beneficial effect on the visco-elastic and pasting properties of the food mix. Rice flour has become a strikingly important ingredient due to its unique attributes such as bland taste, white color and hypoallergenicity (Bazaz et al, 2016), which makes it appropriate to be utilized as a constituent of complementary food. Rice flour has its advantages in designing food products in which textural prerequisites needs to be manipulated in order to get the optimum responses within limited constraints. Hence, the determination of optimal proportion of ingredients becomes crucial in multi-component system which has been appropriately solved by the mixture model design. The capacity of having high water absorption index and low solubility makes protein isolates possess suitable gelation and pasting properties which is a customary property of a complementary infant food.

3.5.Effect of variables on Overall Acceptability Y_4: The contour presented in Fig. 1 describes that the overall acceptability of the complementary food was able to describe 97.48% (Table 1) of effect of variation in the formulation of the complementary mix which is expressed in the quadratic mixture equation no. 4. From ANOVA, the model F 76.34 value of ($p=0.0001$) implies that there was a significant effect of the rice flour, potato flour and protein isolate on the acceptability of the product (fig 2).

Overall Acceptability

$$Y_4=-29.7081A-123.229B-74.5029C+317.501AB+269.4074AC+115.942BC \quad (6)$$

It is observed that individual component A, B and C did not have a strong impact on the overall acceptability of the mix, however, the interactive terms increased the acceptability of the mix a considerably. It may be due to the fact that in the mixture design the interaction between the individual physicochemical properties of the potato flour, rice flour and chickpea protein isolates compliments each other, which may not be possible in using a single food matrix Enhancement of Overall acceptability of the complementary food is due to improvement in the consistency, mouth feel and taste which has been significantly improved by the increment of potato flour and protein isolate. Potato flour has been found to increase the acceptability and textural properties by other studies also (Olatunde et al, 2020).

3.6.Optimization of Complementary food

The optimized formulation was selected with the goal of maximizing the overall acceptability (Y_4) of the complementary food mix and keeping the physicochemical properties WAC (Y_1), WSI (Y_2) and texture (Y_3) within range. Within these constraints, d optimal design selected the variation 65A:28.1B:6.9C as the most desirable one, Where A=Rice flour; B=Potato flour and C= Protein isolates

Verification of the Model: Verification of data is done by the Design Expert software, by calculating the Relative Standard Error (RSE) %.

$$RSE\ \% = \frac{\text{Actual value-Predicted value}}{\text{Predicted value}} \times 100 \quad (7)$$

The predicted and observed values of the analyzed responses (Table 2) were compared in order to check the adequacy of the surface response equation. The observed responses were analyzed against the predicted ones where no significant differences ($p<0.05$) among them showed that the results were found to be in good agreement with the predicted values. This shows that the basic composition of the complementary food mix could be manipulated using the three dimensional special model where variation in more than one factors affects the optimization process and has to find the best fit within a given limit of constraints. Food mix thus developed has optimal physicochemical properties well suited within the limits of multiple factors.

4.Conclusions

In the optimized complementary food mix formula out of the three components, Potato flour had better positive effect on the Water Absorption Capacity (WAC), Water Solubility Index (WSI) and texture; followed by the Chickpea protein isolates and Rice flour. Since, the physicochemical properties of all the three components are diverse the optimization was possible only on the basis of the combined impact between the interactive (intercept) terms. Thus, the lowest content of Rice flour (65g) and maximizing the potato flour (28.1g) with chickpea protein isolate (6.9g) yielded the best possible combination to get the optimal complementary mix. This study exploits the use of starches and chickpea protein isolates to develop a weaning food which is not only utilizes easily available food items with a year-round availability and highly economical but also has optimal physicochemical properties, energy dense and hypoallergenic containing highly bioavailable protein source which could be utilized for mass supplementation programs.

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