*Biological Forum – An International Journal* **15(2): 461-466(2023)**

**ISSN No. (Print): 0975-1130**
**ISSN No. (Online): 2249-3239**

# Optimization of Pearl Millet and Carrot based Gluten-free Pasta using Response Surface Methodology

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*(Received: 15 December 2022; Revised: 30 January 2023; Accepted: 09 February 2023; Published: 15 February 2023)*
*(Published by Research Trend)*

**ABSTRACT: Pasta is a convenient, ready-to-cook extruded product that is consumed worldwide. Usually, pasta is prepared using wheat as a major ingredient comprising gluten. Gluten possesses some allergic behaviour that leads to gluten-related disorders. The present study aims to formulate a Gluten-Free (GF) pasta with pearl millet flour, tapioca flour and carrot powder as significant ingredients. Pearl millet, tapioca and carrot serves as an effective gluten-free alternative, packed with high nutritional value. The development of gluten-free pasta includes the addition of pearl millet flour (PMF) and carrot powder (CP) at different proportions. The developed GF pasta samples were optimized through response surface methodology (RSM) using colour, texture and overall acceptability as responses. Based on the responses the treatment with 12% of carrot powder and 58% of pearl millet resulted in higher sensory scores for colour, texture, and overall acceptability, which were determined to be 8.7, 8.5 and 8.8 respectively. The optimized treatment was found to have the maximum desirability. Thus, the results demonstrate that the optimized gluten-free pasta has higher acceptability, besides its benefit as a gluten-free product.**

**Keywords:** Pasta, gluten-free pasta, millet pasta, optimization, response surface methodology.

## INTRODUCTION

Food and Nutrition Board of the National Academy of Sciences defined functional foods as “any food ingredient or modified food that possess nutritional composition beyond the amount it actually contains”. Pasta can also be called a functional food when it is fortified with healthy alternatives. Pasta is world’s favourite food because of its exquisite taste, ease of preparation, and variety. Pasta is usually prepared semolina and/or wheat flour, and water (Phongthai *et al*., 2017). Pasta is formed into various shapes from a basic mixture of wheat endosperm and water, and later cooked fresh or dried for later consumption. Pasta is low in fat, high in complex carbohydrates, essential vitamins and minerals, and low in sodium (Kaur *et al.,* 2011). The strength of pasta dough depends on gluten which maintains its consistency and elasticity as wheat products have traditionally been used to make it (Kruger *et al*., 1996).

Celiac Disease (CD) is an immune-mediated enteropathy (disease of the intestine) provoked by the consumption of gluten in genetically predisposed people. It is one of the most prevalent chronic disorders in the world (Catassi *et al.,* 2007). The villi of the small intestine are harmed by the consumption of gluten because they are unable to metabolize certain cereal prolamin (Meybodi *et al*., 2015). Therefore, it is best to avoid using such proteins in the diets of CD patients and people found to have allergies to those proteins. Hence, there has been a huge demand and scope for developing gluten-free food products (Cayres *et al*., 2020).

Pearl millet is a highly nutritious food, nutritionally comparable and even superior to other major grains for energy, protein, vitamins and minerals. Pearl millet has been found to be significantly rich in resistant starch, soluble and insoluble fibre, minerals and antioxidants (Johari *et al*., 2016). Carrot is a crunchy, tasty and highly nutritious root vegetable. There is good reason to include carrots in the human diet as they are loaded with carotenoids, phenolic compounds, polyacetylenes and vitamins and this may help reduce the risk of some diseases (da Silva Dias, 2014). Starch is added to pasta production to enhance the appearance, texture smoothness, and mouth feel of the finished product (Nilusha *et al*., 2019). The starches derived from potatoes, rice, and tapioca are naturally devoid of gluten and are employed in gluten-free formulations (Rai *et al*., 2018).

Gull *et al*. (2015) optimized pasta using composite flour (CF) of finger millet flour (FMF) and pearl millet flour

(PMF) and carboxy methyl cellulose (CMC) at different proportions and studied their effect on firmness, lightness, gruel loss and overall acceptability of the pasta. High desirability was obtained for the pasta with 20g FMF, 12g PMF and 4g CMC. Sinthiya (2019) optimized wheat and foxtail millet pasta added with guar gum using gluten content, glycemic index, cooking time and cooking loss and sensory attributes as responses. Rathi *et al.* (2004) developed highly acceptable pasta using depigmented pearl millet flour which was optimized using response surface methodology. The present study was conducted with the objective of optimizing the raw materials (pearl millet flour and carrot powder) based on the sensory attributes to develop the pearl millet and carrot based gluten-free pasta.

## MATERIALS AND METHODS

**Raw materials.** The pearl millet flour, carrot powder, tapioca flour, xanthan gum and other ingredients were the raw ingredients used in this study, were procured from the local market. The physical properties of ingredients were analysed as per standard protocol (Sharon *et al*., 2015).

**Experimental design.** Response Surface Methodology (RSM) uses quantitative data from appropriate experimental designs to determine and simultaneously solve multivariate equations that can be graphically represented as response surfaces. D-Optimal Mixture Design was chosen to determine the combinations of experiment where, 30% of tapioca flour is added in standardized proportion pearl millet flour (50-66%) and carrot powder (4-20%) were considered as independent variables. The total number of 13 runs generated was given in Table 1. The sensory attributes like colour, texture and overall acceptability are considered as dependent variables. The effect of raw materials like pearl millet flour and carrot powder on colour and appearance, texture and overall acceptability of the gluten-free pasta were evaluated. Regression analysis was done to assess the effect of pearl millet flour and carrot powder on all the dependent variables.

**Table 1: Experimental design with actual values of independent variables using D-optimal mixture design.**

| RUN | COMPONENT 1<br>A: Pearl millet flour (PMF) (g) | COMPONENT 2<br>B: Carrot powder (CP) (g) |
|---|---|---|
| 1 | 58 | 12 |
| 2 | 66 | 4 |
| 3 | 50 | 20 |
| 4 | 50 | 20 |
| 5 | 58 | 12 |
| 6 | 66 | 4 |
| 7 | 50 | 20 |
| 8 | 58 | 12 |
| 9 | 66 | 4 |
| 10 | 66 | 4 |
| 11 | 50 | 20 |
| 12 | 54 | 16 |
| 13 | 62 | 8 |

### Determination of dependent variables

**Preparation of gluten free pasta.** The experimental pasta samples were prepared using Dolly - La Monferrina mini pasta-making machine All the dry ingredients were weighed and mixed in the extruder during kneading phase. 42% of moistening condition (40% water + 2% gum) and 8% of oil is added to the dry ingredients. Then the ingredients were kneaded in the mixing chamber of the extruder for 10-15 minutes. After the kneading the contents were extruded out through the die attached with the blades for short-sized pasta. The extruded pasta samples were dried in a cabinet tray dryer at 60°C for about 3-4 hrs. The pasta samples were then were cooked at optimum time and temperature.

All the cooked pasta samples were subjected to sensory analysis. The pasta samples were subjected to twenty semi-trained panel members. The panellists were asked to evaluate the sensory quality of samples in the sensory scorecard. Judging of samples is based on the sensory attributes like appearance and colour, taste, texture, flavour and overall acceptability, indicating the degree of liking on a 9-point hedonic scale.

## RESULTS AND DISCUSSION

Experiments were conducted to optimize the level of pearl millet flour and carrot powder incorporation to develop the gluten-free pasta by examining the effect of pearl millet flour and carrot powder on the sensory attributes like colour and appearance, texture and overall acceptability of the pasta. The chosen responses of the experimental design were given in Table 2.

**Table 2: Experimental design along with chosen responses for the formulated pasta.**

| Run | Component 1 A: Pearl millet flour (PMF) (g) | Component 2 B: Carrot powder (CP) (g) | Response 1 Colour and appearance | Response 2 Texture | Response 3 Overall acceptability |
|---|---|---|---|---|---|
| 1 | 58 | 12 | 8.7 | 8.6 | 8.9 |
| 2 | 66 | 4 | 7.9 | 7.7 | 8.5 |
| 3 | 50 | 20 | 7.7 | 7.4 | 7.8 |
| 4 | 50 | 20 | 7.7 | 7.4 | 8.1 |
| 5 | 58 | 12 | 8.8 | 8.7 | 8.9 |
| 6 | 66 | 4 | 7.9 | 7.7 | 8.1 |
| 7 | 50 | 20 | 7.8 | 7.6 | 8.1 |
| 8 | 58 | 12 | 8.6 | 8.5 | 8.8 |
| 9 | 66 | 4 | 7.8 | 7.6 | 8.3 |
| 10 | 66 | 4 | 7.6 | 7.3 | 7.7 |
| 11 | 50 | 20 | 7.6 | 7.3 | 8 |
| 12 | 54 | 16 | 8.6 | 8.4 | 8.8 |
| 13 | 62 | 8 | 8.4 | 8.2 | 8.6 |

**Effect of independent variables on the colour and appearance of pasta.** Colour and appearance are an important parameter plays major role in the visual perception of the product. The colour and appearance of the developed gluten-free pasta ranged from 7.6 to 8.8 (9-point hedonic scale) was given in Table 2. The experimental results of the colour and appearance fitting well to the regression model. The results indicates that the Model F-value of 90.75 implies the model is significant. There is only a 0.01% chance that a F-value this large could occur due to noise. Lack of fit was found to be non-significant which indicates that the model was good. The $R^2$ value was found to be 0.9478 and the adjusted $R^2$ was found to be 0.9373. The ratio was greater than 4 which was ideal to direct the design. Taking all the above criteria into account, the model (Eqn. 1) was opted to characterize the variance in the colour and appearance. The quadratic model obtained in terms of actual variables from regression analysis was as follows:

$$CO = 0.0943197 * PMF - 0.601384 * CP + 0.0150281 * PMF * CP \quad (1)$$

From the formula it is evident that the colour and appearance had a highly significant (P<0.0001) positive linear effect of pearl millet flour (PMF) and a negative linear effect of carrot powder (CP). The quadratic term indicates that the pearl millet flour (PMF) and carrot powder (CP) showed significant (P<0.0001) positive effect. Rathi *et al.* (2004) reported significant (p≤0.05) improvement in overall acceptability with improvement in colour through de-pigmentation in pearl millet pasta. The effect of pearl millet flour and carrot powder on the colour and appearance was observed from Fig. 1. Decreased PMF (50%) and increased CP (20%) significantly decreases the colour and appearance of the pasta. Similarly increased PMF (66%) and decreased CP (4%) also negatively affect the colour and appearance of the pasta.

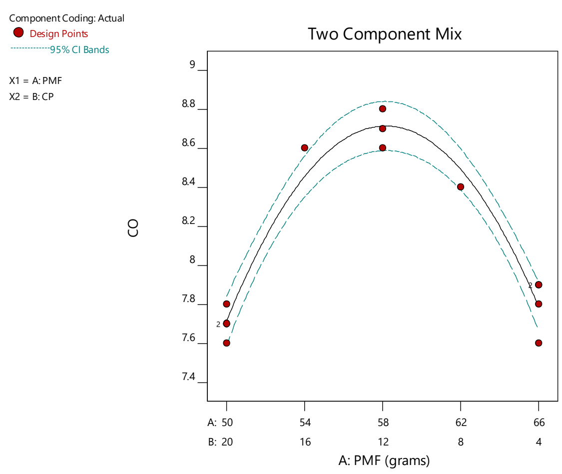


**Fig. 1.** Effect of pearl millet flour and carrot powder on the colour and appearance of gluten-free pasta.

**Effect of independent variables on the texture of pasta.** Texture plays a vital role in the pasta which enhance the mouth feel of the pasta. The texture of the developed gluten free pasta ranged between 7.3 to 8.7(9-point hedonic scale) was presented in Table 2. The experimental results for the texture of the pasta fitted well in the regression model. The experimental results shows that the Model F-value of 73.09 infers the model is significant. There is only 0.01% chance that this large F-value could occur due to noise. Lack of fit shows non-significant that indicates the model was perfect. The $R^2$ value was 0.9360 and the adjusted $R^2$ was found to be 0.9232. In adequate precision, the ratio was found to be greater than 4 is required and indicates that the signal is adequate and the model can be used to navigate the design. With all the above-mentioned criteria, the model (Eqn. 2) was selected to represent the variance in the texture.The quadratic model obtained in relation of actual variables from the regression analysis for lateral expansion was as follows:

$$TX = 0.0888849 * PMF - 0.70344 * CP + 0.0170646 * PMF * CP \quad (2)$$

From the formula it is obvious that the texture had a significant (P<0.0001) positive linear effect of pearl millet flour (PMF) and a negative linear effect of carrot powder (CP). The quadratic term shows that the pearl millet flour (PMF) and carrot powder (CP) showed highly significant (P<0.0001) positive effect. Yadav *et al*. (2014) studied that addition of carboxy methyl cellulose and whey protein concentrate had positive effect on the overall acceptability which attributed to the textural properties of the pasta developed with pearl millet and barley flour. Fig. 2 shows the effect of pearl millet flour and carrot powder on the texture of the gluten-free pasta. The higher texture value of 8.5918 was observed in 58% of PMF and 12% of CP.

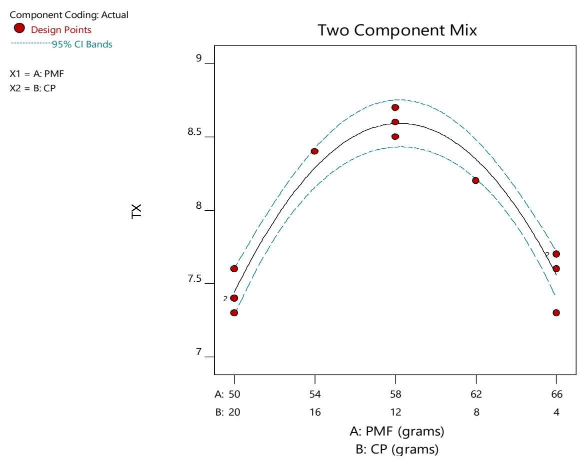


**Fig. 2.** Effect of pearl millet flour and carrot powder on the texture of gluten-free pasta.

**Effect of independent variables on the overall acceptability of the pasta.** Overall acceptability gives the overall sensory analysis of the gluten-free pasta. The overall acceptability of the formulated gluten-free pasta was found between 7.7 and 8.9 (9-point hedonic scale) was given in Table 2. The experimental results for the overall acceptability of the pasta fitted well in the regression model. The experimental results shows that the model F-value of18.50 specifies the model is significant and shows the variation in responses. There is only 0.04% chance that large F-value could arise due to noise. Lack of fit was observed to be non-significant infers that the model fit the actual data within the limit. The coefficient of regression $R^2$was found to be 0.7872 and the adequate $R^2$ was 0.7447. The signal and noise ratio was greater than 4 which was found to be 8.408 indicates the adequate signal and the model can be used to navigate the design space. From the above-mentioned conditions, the model (Eqn. 3) was chosen to characterize the variance in overall acceptability. The quadratic model obtained in terms of actual variables from regression analysis was as follows:

$$OA = 0.102325 * PMF - 0.481104 * CP + 0.0125234 * PMF * CP \quad (3)$$

The formula shows that the overall acceptability had a highly significant (P<0.0001) positive linear effect of pearl millet flour (PMF) and a negative linear effect of carrot powder (CP). The quadratic term indicates that the pearl millet flour (PMF) and carrot powder (CP) showed significant (P<0.0001) positive effect. Similar result was found by Sinthiya (2019) who used response surface methodology to optimize the use of Composite flours of wheat, foxtail millet and guar gum to develop gluten free millet noodles and observed that when the foxtail millet flour increases the sensory scores of the noodles decreases.

Fig. 3 shows the effect of pearl millet flour and carrot powder on the overall acceptability of the gluten-free pasta. The overall acceptability of the pasta was found to be higher at 58% of PMF and 12% of CP. The increased and decreased content of both pearl millet flour and carrot powder negatively affect the overall acceptability of the product.

**Table 3: ANOVA results for quadratic model.**

| Source | Colour & Appearance | | Texture | | Overall Acceptability | |
|---|---|---|---|---|---|---|
| | F-value | P-value | F-value | P-value | F-value | P-value |
| Model | 90.75 | < 0.0001 | 73.09 | < 0.0001 | 18.50 | 0.0004 |
| AB | 180.69 | < 0.0001 | 144.79 | < 0.0001 | 36.35 | 0.0001 |
| Lack of fit | 1.26 | 0.3351 | 0.8340 | 0.4688 | 0.3551 | 0.7116 |
| $R^2$ | 0.9478 | | 0.9360 | | 0.7872 | |
| Adj $R^2$ | 0.9373 | | 0.9232 | | 0.7447 | |
| Adeq precision | 18.1047 | | 16.4751 | | 8.4083 | |

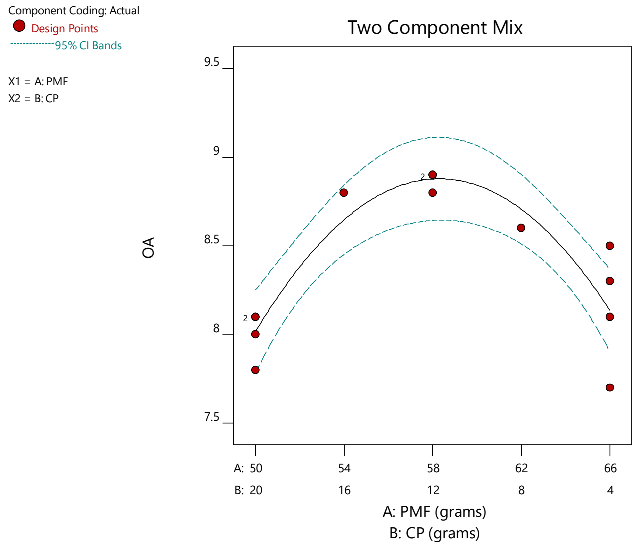


**Fig. 3.** Effect of pearl millet flour and carrot powder on the overall acceptability of gluten-free pasta.

**Optimization of gluten-free pasta.** For optimization, numerical multi-response technique was employed (Park *et al*., 1993) to choose the best proportion of pearl millet flour and carrot powder to get highly acceptable gluten-free pasta. The Goal for optimization for the development of gluten-free pasta, predicted and actual values of responses are given in Table 4. From the analysis, optimum solution for components and responses are given in Table 5.

**Table 4: Goal for optimization along with predicted and actual values of responses.**

| Constraints | Goal | Lower limit | Upper limit | Predicted value | Actual value |
|---|---|---|---|---|---|
| PMF: Pearl millet flour | In range | 50 | 66 | - | - |
| CP: Carrot powder | In range | 4 | 20 | - | - |
| CO: Colour & Appearance | Maximize | 7.6 | 8.8 | 8.714±0.115 | 8.08±0.115 |
| TX: Texture | Maximize | 7.3 | 8.7 | 8.592±0.145 | 7.88±0.145 |
| OA: Overall acceptability | Maximize | 7.7 | 8.9 | 8.879±0.213 | 8.35±0.213 |

**Table 5: Optimum solution for components and responses.**

| Number | PMF | CP | CO | TX | OA | Desirability | |
|---|---|---|---|---|---|---|---|
| 1 | 58.211 | 11.789 | 8.714 | 8.592 | 8.879 | 0.944 | Selected |

## CONCLUSIONS

This study demonstrated that, both PMF and CP affects the sensory attributes like colour and appearance, texture and overall acceptability when different proportion of pearl millet flour and carrot powder were used to formulate the gluten free pasta with standardized amount of tapioca flour and xanthan gum. The optimized product with 58% of PMF and 12% of CP resulted in higher sensory attributes. Addition of tapioca flour and xanthan gum increased the structural stability of the developed gluten-free pasta. People with celiac disease have a serious gluten intolerance and need to eat gluten-free meals to stay well. Other people may have nonceliac gluten sensitivity and find that cutting out gluten reduces gas and bloating. Some individuals choose to follow a gluten-free diet because they believe it to be more healthful. By eliminating the gluten-causing disorder and to maintain a healthy food choice, a gluten-free diet can meet their demands. Commercialization of the product will serve as a healthy alternative for all age group, especially for people with gluten related disorders. Developed gluten-free pasta can satisfy the taste, satiety-oriented dieting and promote healthy aesthetic food habit of consumers.

**Acknowledgement.** The authors are thankful to Tamil Nadu Veterinary and Animal Sciences University for the financial support and for providing the required facilities during the study.

**Conflict of Interest.** None.

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**How to cite this article:** Anitha S., Esther Magdalene Sharon M., Marx Nirmal R. and Mathanghi S.K. (2023). Optimization of Pearl Millet and Carrot based Gluten-free Pasta using Response Surface Methodology. *Biological Forum – An International Journal, 15*(2): 461-466.