***Original Research Article***

**CHARACTERIZATION AND OPTIMIZATION OF GARLIC-INCORPORATED PASTA: PHYSICOCHEMICAL, FUNCTIONAL AND TEXTURAL PROPERTIES**

**ABSTRACT**

The present study aimed to develop the dried garlic incorporated pasta with variations in garlic forms (grit and powder), garlic quantity (0.0-2.0%), and drying temperature of prepared pasta (50-80ºC). Nutritional composition, allicin content, antioxidant activity, cooking quality (optimum cooking time, gruel loss, water absorption capacity, swelling index), and uncooked and cooked textural properties were measured for the prepared pasta. A three-way ANOVA test was performed for the measured parameters at the significant levels of 1%, 5%, and 10%. The allicin content found an insignificant difference when adding the same quantity of garlic forms (powder or grit). It decreased insignificantly at lower drying temperatures (50 and 60°C) and losses higher at 70ºC (17.58-20.02%) and 80°C (30.62-31.40%). The antioxidant activity decreased by 16.32% and 34.86% at 70 and 80°C drying temperatures, respectively, but negligible difference was observed at lower temperatures (50 and 60ºC) at the same condition. The optimum cooking time of pasta samples was increased with an increase in the drying temperature (50°C to 80°C) and quantity of dried garlic (0.5% to 2.0%) but decreased with garlic grits instead of garlic powder compared to control pasta. The firmness of cooked pasta was found to be higher at 60°C then dried at 50, 70, and 80°C. The gruel loss was found to be maximum at 50ºC drying temperature of prepared pasta. Based on the measured parameters, the best garlic-incorporated pasta was found to be 1.5% garlic powder incorporated and dried at 60°C.

***Keywords:*** *Pasta, Garlic, Allicin, Antioxidant activity, Drying, Functional, 3-Way ANOVA*

**1. INTRODUCTION**

Globally, cereal-based foods are extensively consumed since they contribute significantly to most cultural activities and provide high amounts of carbohydrates (Topping, 2007). Pasta is one of the most highly demandable foods, mainly made from durum wheat semolina and water, prepared by several unit operations. It is mainly in focus due to its flexibility and affordability among instant food products. Semolina is the richest source of carbohydrates, but it lacks phytochemicals, particularly phenolics, flavonoids and organosulfur compounds. Nowadays, people are diverting towards functional instant foods prepared from natural sources with high nutritional value. Functional foods prepared by fortification with natural sources such as garlic, onion, carrot, and green vegetables are a novel approach to preparing pasta with a vehicle to deliver phytochemicals.

Considering garlic's natural and wealthiest bioactive profile, it is unique among all other food products. It is mainly attributed to the three phytochemicals groups: fructans, phenolics, and organosulfur compounds (Shang *et al*., 2019). Garlic is cultivated worldwide in temperate climates. The total annual garlic production was 28 million tons in an area of 1.6 million hectares (FAOSTAT, 2023). India and China are the major producing countries that account for approximately 80% of world production. It is one of the most important sources of volatile and non-volatile compounds. Volatile compounds impart flavour, whereas non-volatile compounds, namely proteins, minerals, and phytochemicals, are well known for their therapeutic properties (Rekowska and Skupień, 2009). Garlic is the richest source of organosulfur compounds (Prati *et al*., 2014) and the third major phenolic compound (Vinson *et al*., 1998) among vegetables. Various researchers mentioned that garlic has defensive properties against various ailments, namely cardiovascular, diabetic, cancer, atherosclerosis, hypoglycaemic, microbial activity, antidote, hepatoprotective, and platelet aggregatory activity (El-Saber Batiha et al., 2020; Sobenin et al., 2010).

Garlic can be used in different forms, including paste, essential oil, aged garlic extract, black garlic, pickle, flakes, and powder (Prakash & Prasad, 2023b). Among these forms of garlic, dried garlic powder occupies a unique position. The main reasons are its ease of storage, decreasing transportation cost, extended shelf life, and, most notably, versatile application in foods and pharmaceutical industries as a functional ingredient for easy amalgamation behaviour (Demiray and Tulek, 2014). Researchers have attempted to develop processed products, viz. white pan bread (Hong and Shin, 2008) and sponge cake (Lee *et al*., 2009; Shin *et al*., 2007), to improve quality attributes using garlic powder. Based on the above facts, the main objective of this research work was to formulate the garlic fortified pasta rich in phytochemicals. The research objective is also to determine the effect of drying at different temperatures on Allicin, phenol, antioxidant, textural and cooking properties of prepared garlic-incorporated pasta. The present research will have the potential to overcome the phytochemical deficiency of pasta consumers.

**2. MATERIALS AND METHODS**

**2.1. Materials**

Semolina was procured from a shopping mart in Sangrur, Punjab, India. Garlic forms (powder and grit) were prepared from cultivated variety Haryana garlic-17 (HG-17). All the chemicals used in the current research work were of analytical grade. (n-(2-hydroxyethyl) piperazine-n'-(2-ethanesulphonic acid) (HEPS) buffer, 5,5’-dithio-bis-(2-nitrobenzoic acid) (DTNB), L-cysteine, Folin-Ciocalteu reagent, 2,2-Diphenyl-1-picrylhydrazyl (DPPH), and sodium nitrite were purchased from Central Drug House Pvt. Ltd. (India). Gallic acid and quercetin standards were purchased from Loba Chemie Pvt. Ltd. (India).

**2.2. Methods**

**2.2.1 Preparation of pasta**

The experimental design of pasta formulations is represented in Table 1. Forty different dried pastas were prepared, consisting of three independent variables (Semolina and garlic ratio, garlic form and dehydration temperature). According to the World Health Organization the quantity of dried garlic was used to be 0.4 to 1.2 g/day (Prati et al., 2014). The consumption of garlic per day as a dietary supplement was recommended between 600 to 900 mg by the American Dietetic Association, 2004 (Rana et al., 2011). Based on recommendations by the various agencies, the garlic forms were considered between 0.0-2.0 g in this research. The pasta was prepared with semolina and garlic form (Grit or powder) and dry mixed thoroughly in a Hobart mixer (5KPM50, USA) for 5 min at low speed. Distilled water (17 ml) was added per 100 g of mixed flour and then kneaded until the dough was consistent for lamination. The prepared dough was passed through a low-shear single screw extruder (Model: La Monferrina, Italy) with a ziti-cut tubular shape die having a diameter of 7 mm. The pasta was cut into 2.5 to 2.8 cm length with an automatic knife cutter moving over the outer surface of the die. The freshly prepared Ziti-cut tubular pasta moisture content was about 28%. It was dehydrated in a static drier of 50, 60, 70 and 80°C preset temperatures up to constant weight. The dried pasta was separately stored in zip-lock pouches for further study.

**Table 1. Treatment codes for formulations of pasta**

|  |  |
| --- | --- |
| Semolina: Garlic | Drying temperature and garlic form |
| 50°C | 60°C | 70°C | 80°C |
| Powder | Grit | Powder | Grit | Powder | Grit | Powder | Grit |
| 100:0 | T0150 / T0250 | T0160 / T0260 | T0170 / T0270 | T0180 / T0280 |
| 99.5:0.5 | T1150 | T1250 | T1160 | T1260 | T1170 | T1270 | T1180 | T1280 |
| 99:1 | T2150 | T2250 | T2160 | T2260 | T2170 | T2270 | T2180 | T2280 |
| 98.5:1.5 | T3150 | T3250 | T3160 | T3260 | T3170 | T3270 | T3180 | T3280 |
| 98:2 | T4150 | T4250 | T4160 | T4260 | T4170 | T4270 | T4180 | T4280 |

**2.2.2. Proximate composition**

Protein, fat and ash contents of semolina, dried garlic flakes, and pasta samples were determined (AOAC, 2006). Carbohydrate content was estimated between the difference of 100 and the sum of moisture, protein, fat and ash content.

**2.2.3. Allicin content (AC), total phenol content (TPC), total flavonoid content (TFC), and antioxidant activity (AA) analysis**

AC in the dried garlic flakes (55°C), garlic blend and control pasta were measured using spectrophotometric method (Prakash & Prasad, 2023a).The solvent extraction technique was adopted for sample preparation (Yuksel et al., 2017). The solvent extracted sample was used for estimation of TPC, TFC, and AA. TPC in the extracted samples was estimated using Folin–Ciocalteu reagent (Gull et al., 2018). Quercetin was taken as a standard for estimating total flavonoid content (TFC) in the prepared samples (Yuksel et al., 2017). AA was measured using DPPH (Gull et al., 2018).

**2.2.4. Textural properties**

The pasta firmness/stickiness rig method was used to analyze the textural parameters of uncooked/cooked pasta samples using a textural analyzer (TA-XT2i, Stable Microsystems, Surrey, UK). The individual samples were vertically placed on the rectangular aluminium probe, and a compression force of 1000 g was applied for 2 sec to a withdrawal distance of 10.0 mm. The pre-test, test, and post-test speeds were 1.0 mm/s, 0.5 mm/s, and 10.0 mm/s, respectively. Cooked pasta was prepared using the help of previously pre-determined OCT. Immediately, it was cooled down at room temperature using distilled water. The resultant force-time curve was used to estimate the hardness (N) and fracturability (mm) of uncooked pasta and firmness (N) and work of adhesion (g.sec) of cooked pasta samples. The textural properties of uncooked/cooked pasta were performed in triplicate.

**2.2.5. Cooking quality of pasta**

The optimal cooking time (OCT) of pasta was determined (AACC, 2000). The cooking test was performed separately for individual pasta treatments to decide their OCT. Briefly, 300 ml (approx.) of boiling water was used to cook the 10.0 g of pasta. The OCT was considered after the disappearance of the white core portion in the pasta after squeezing. Each pasta treatment sample was optimally cooked to pre-determined OCT to estimate gruel loss. Gruel loss (GL) was estimated by evaporating the cooked water in a forced air drier at 110°C up to constant weight. The water absorption capacity of pasta was estimated using equation 1.

$Water absorption (\%)=\frac{Weight of cooked product-Weight of raw pasta}{Weight of raw pasta}×100$ (1)

The swelling index (SI) of cooked pasta is the ratio of the water (g) absorbed by the dried pasta (g). It was calculated using the equation 2.

$Swelling index=\frac{Weight of cooked product-Weight after drying (105°C)}{Weight after drying (105°C)}$ (2)

**2.2.6. Statistical analysis**

Analyzed parameters were performed thrice and represented as arithmetic mean± standard deviation. Analysis of variance (ANOVA) of individual analyzed parameters was performed using minitab17 statistical software to find out the significance level at 1%, 5%, and 10%.

**3. RESULTS AND DISCUSSION**

**3.1. Chemical composition of raw materials**

The ingredients used for the pasta formulation were analyzed for proximate composition, AC, TPC, TFC, and AA (Table 2).

**Table 2. Chemical composition of raw materials**

|  |  |
| --- | --- |
| Parameters  | Raw materials |
| Durum semolina | Dried garlic (55°C) |
| Protein (% db)  | 12.07±0.06b | 25.83±0.40a |
| Fat (% db)  | 0.56±0.02b | 0.86±0.04a |
| Ash (% db)  | 0.67±0.02b | 3.42±0.13a |
| Carbohydrate (% db)  | 86.70±0.10a | 69.89±0.23b |
| AC (mg/100g, db)  | 0.00±0.00b | 898.45±21.60a |
| TPC (mg gallic acid/100 g, db)  | 78.12±1.05b | 257.68±8.00a |
| TFC (mg quercetin /100g, db)  | 58.26±1.10b | 511.00±31.29a |
| AA (%, db)  | 3.48±0.09b | 23.59±0.72a |

Results are mentioned as mean±S.D (n=3). Different superscript alphabets in the same row on mean values differ significantly (*p*≤0.05).

**3.2. Effect on proximate composition of garlic incorporated pasta**

The proximate parameters (on db) of different erratic compositions of semolina and dried garlic ratio (100:0, 99.5: 0.5, 99.0:1.0, 98.5:1.5, and 98.0:2.0%), garlic forms (powder and grit), and drying temperatures (50, 60, 70, and 80°C) of pasta were represented in Table 3. The protein and ash content were significantly increased with an increase in the quantity of garlic, and no significant changes were observed in fat content in prepared pasta dried between 50-80ºC and forms of garlic (powder and grit).

**Table 3. Chemical composition of garlic forms concentrations incorporated pasta dried at different temperatures**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment code | Protein(% db) | Fat(% db) | Ash(% db) | Carbohydrate(% db) | Treatment code | Protein(% db) | Fat(% db) | Ash(% db) | Carbohydrate(% db) |
| Garlic powder | Garlic grit |
| T0150 | 11.68 | 0.55 | 0.65 | 87.12 | T0250 | 11.68 | 0.55 | 0.65 | 87.12 |
| T1150 | 11.76 | 0.55 | 0.66 | 87.03 | T1250 | 11.76 | 0.55 | 0.66 | 87.03 |
| T2150 | 11.86 | 0.55 | 0.68 | 86.92 | T2250 | 11.85 | 0.55 | 0.68 | 86.92 |
| T3150 | 11.96 | 0.55 | 0.69 | 86.79 | T3250 | 11.96 | 0.55 | 0.69 | 86.79 |
| T4150 | 12.04 | 0.56 | 0.71 | 86.70 | T4250 | 12.03 | 0.55 | 0.71 | 86.71 |
| T0160 | 11.66 | 0.54 | 0.65 | 87.15 | T0260 | 11.66 | 0.54 | 0.65 | 87.15 |
| T1160 | 11.76 | 0.55 | 0.66 | 87.03 | T1260 | 11.73 | 0.55 | 0.66 | 87.06 |
| T2160 | 11.85 | 0.55 | 0.68 | 86.92 | T2260 | 11.81 | 0.55 | 0.68 | 86.97 |
| T3160 | 11.93 | 0.55 | 0.69 | 86.83 | T3260 | 11.90 | 0.55 | 0.69 | 86.86 |
| T4160 | 12.00 | 0.55 | 0.71 | 86.74 | T4260 | 12.00 | 0.55 | 0.71 | 86.74 |
| T0170 | 11.43 | 0.53 | 0.63 | 87.40 | T0270 | 11.43 | 0.53 | 0.63 | 87.40 |
| T1170 | 11.51 | 0.54 | 0.65 | 87.31 | T1270 | 11.45 | 0.53 | 0.64 | 87.39 |
| T2170 | 11.63 | 0.54 | 0.66 | 87.17 | T2270 | 11.53 | 0.54 | 0.66 | 87.27 |
| T3170 | 11.70 | 0.54 | 0.68 | 87.08 | T3270 | 11.61 | 0.54 | 0.67 | 87.18 |
| T4170 | 11.79 | 0.54 | 0.69 | 86.97 | T4270 | 11.70 | 0.54 | 0.69 | 87.07 |
| T0180 | 11.33 | 0.53 | 0.63 | 87.51 | T0280 | 11.33 | 0.53 | 0.63 | 87.51 |
| T1180 | 11.35 | 0.53 | 0.64 | 87.56 | T1280 | 11.38 | 0.53 | 0.64 | 87.45 |
| T2180 | 11.36 | 0.53 | 0.65 | 87.46 | T2280 | 11.45 | 0.53 | 0.65 | 87.36 |
| T3180 | 11.58 | 0.54 | 0.67 | 87.21 | T3280 | 11.56 | 0.53 | 0.67 | 87.24 |
| T4180 | 11.69 | 0.54 | 0.69 | 87.08 | T4280 | 11.65 | 0.54 | 0.69 | 87.12 |

**3.3. Effect on AC, TPC, TFC, and AA of garlic incorporated pasta**

AC (mg/100g), TPC (mg gallic acid/100g), TFC (mg quercetin/100g) and AA (% DPPH scavenging activity) of different combinations of prepared pasta were estimated on a dry basis (Table 4). ANOVA table of estimated parameters, namely AC, TPC, TFC, and AA, was mentioned at 1%, 5% and 10% significant levels with all the sources of pasta combination (Table 5). The AC, TPC, TFC, and AA were found significantly higher in garlic powder-prepared pasta than in garlic grit when the same quantity of garlic forms was added. This might be due to the garlic powder showing cohesion behaviour due to a higher open surface area when compared to grit. Reducing the size of particles has been observed to enhance cohesion behaviour due to the increase in particle surface area per unit mass, thereby promoting a higher number of contact points for inter-particle bonding and facilitating additional interactions. Consequently, this leads to the formation of powders that exhibit greater cohesiveness and reduced flowability (Landillon et al., 2008). AC, TPC, TFC and AA were found to be proportionally increased with an increase in garlic forms (powder or grit) from 0.5 to 2.0%. This might be because garlic is the highest source of AC, and TPC contents, but excellent source of antioxidant activity (Feng et al., 2019).

AC in the garlic incorporated dried pasta (50, 60, 70 and 80°C) was found deceased slightly between 50 and 60°C and losses higher 17.58-20.02% and 30.62-31.40% at 70 and 80°C, respectively. The allicin content in pasta might be degraded under certain conditions, mainly due to heat exposure. It decreased significantly with increasing cooking temperature (Lawson & Wang, 2001). The organosulfur compounds (OSCs) decreased sharply at temperatures 75, 85, and 95°C exposure in heated-blended garlic and after blanching (5 min), allicin content could maintained more than 4.0 mg/g at 75°C, and OSCs of heated-blended garlic paste were found to decrease by 29.56, 90.63, and 94.79% at 75, 85 and 95°C, respectively (Zhang et al., 2021). In another study, the effects of temperature on garlic powder were investigated between 30 and 85°C and found that the allicin concentration is most stable at 30– 35°C and rapidly lost between 70 – 85°C (Mansor et al., 2016).

**Table 4. AC, TPC, TFC and AA of garlic forms of prepared pasta dried at different temperatures**

|  |  |
| --- | --- |
| Semolina: Garlic  | Drying temperature and form of garlic |
| 50°C | 60°C | 70°C | 80°C |
| Powder | Grit | Powder | Grit | Powder | Grit | Powder | Grit |
|  | AC (mg/100g) |
| 100:0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 99.5:0.5 | 4.95±0.11 | 4.90±0.03 | 4.82±0.07 | 4.76±0.03 | 4.06±0.06 | 3.92±0.03 | 3.45±0.05 | 3.36±0.03 |
| 99:1 | 9.82±0.06 | 9.80±0.06 | 9.64±0.09 | 9.53±0.03 | 7.93±0.05 | 7.85±0.03 | 6.94±0.05 | 6.76±0.06 |
| 98.5:1.5 | 14.77±0.05 | 14.79±0.07 | 14.48±0.09 | 14.40±0.11 | 12.44±0.06 | 11.82±0.04 | 10.41±0.06 | 10.26±0.04 |
| 98:2 | 19.72±0.11 | 19.73±0.09 | 19.22±0.04 | 19.08±0.08 | 16.36±0.06 | 16.26±0.03 | 13.84±0.08 | 13.69±0.08 |
| TPC (mg GA/100g) |
| 100:0 | 85.01±3.15 | 83.41±1.43 | 75.35±2.17 | 62.65±1.66 |
| 99.5:0.5 | 86.11±2.16 | 86.15±2.17 | 84.02±1.84 | 83.59±1.91 | 76.35±1.69 | 74.36±2.39 | 62.68±1.68 | 63.36±0.75 |
| 99:1 | 87.08±1.73 | 87.47±1.73 | 85.83±2.24 | 85.84±2.20 | 77.41±1.78 | 75.60±1.92 | 63.60±1.57 | 63.41±1.95 |
| 98.5:1.5 | 88.17±1.86 | 87.97±1.56 | 86.79±1.34 | 86.59±1.53 | 78.62±2.18 | 76.33±2.33 | 64.54±1.78 | 64.60±1.89 |
| 98:2 | 88.81±2.69 | 88.86±2.78 | 87.74±1.20 | 87.74±0.98 | 79.39±2.06 | 76.93±2.01 | 65.76±2.23 | 65.25±2.62 |
| TFC (mg quercetin/100g) |
| 100:0 | 63.35±1.13 | 63.18±1.42 | 56.60±1.63 | 46.48±1.29 |
| 99.5:0.5 | 66.17±1.68 | 66.03±1.87 | 66.07±0.64 | 64.03±1.19 | 58.43±1.35 | 55.52±0.84 | 48.26±1.29 | 46.32±0.97 |
| 99:1 | 68.38±1.18 | 67.83±2.23 | 68.80±1.42 | 67.38±0.93 | 60.75±1.85 | 57.96±1.10 | 49.57±1.31 | 48.40±1.82 |
| 98.5:1.5 | 70.82±1.35 | 71.28±1.49 | 71.33±1.02 | 69.48±1.06 | 63.41±0.82 | 60.41±1.07 | 51.75±1.08 | 50.10±1.15 |
| 98:2 | 73.39±1.37 | 73.39±1.50 | 72.86±1.30 | 71.58±0.68 | 64.92±1.91 | 62.51±1.17 | 53.62±1.09 | 52.40±1.58 |
| AA (% DPPH scavenging activity) |
| 100:0 | 3.37±0.05 | 2.90±0.03 | 2.58±0.04 | 2.23±0.02 |
| 99.5:0.5 | 3.69±0.03 | 3.68±0.05 | 3.64±0.03 | 3.63±0.03 | 2.91±0.03 | 2.86±0.02 | 2.37±0.01 | 2.29±0.02 |
| 99:1 | 3.76±0.06 | 3.75±0.02 | 3.72±0.03 | 3.70±0.03 | 2.95±0.04 | 2.90±0.04 | 2.38±0.01 | 2.32±0.02 |
| 98.5:1.5 | 3.85±0.07 | 3.82±0.03 | 3.82±0.03 | 3.79±0.03 | 3.06±0.04 | 2.91±0.02 | 2.45±0.04 | 2.38±0.03 |
| 98:2 | 3.93±0.06 | 3.90±0.02 | 3.89±0.04 | 3.82±0.03 | 3.21±0.04 | 3.08±0.04 | 2.56±0.02 | 2.48±0.03 |

**Table 5. ANOVA for AC, TPC, TFC and AA of garlic forms of prepared pasta dried at different temperatures**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Source  | AC | TPC | TFC | AA |
| F-value  | ±SEM  | LSD  | F-value  | ±SEM  | LSD  | F-value  | ±SEM  | LSD  | F-value  | ± SEM  | LSD  |
| DT  | \*\*\*  | 0.011  | 0.030  | \*\*\*  | 0.366  | 1.030  | \*\*\*  | 0.246  | 0.693  | \*\*\*  | 0.007 | 0.019  |
| S:G | \*\*\*  | 0.012  | 0.034  | \*\*\*  | 0.409  | 1.151  | \*\*\*  | 0.275  | 0.775  | \*\*\*  | 0.004 | 0.012 |
| GF  | \*\*\*  | 0.008  | 0.022  | NS  | 0.259  | 0.728  | \*\*\*  | 0.174  | 0.490  | \*\*\*  | 0.006 | 0.017 |
| S:G \*GF  | \*\*\*  | 0.017  | 0.048  | NS  | 0.578  | 1.628  | NS  | 0.390  | 1.096  | \*\*\* | 0.010 | 0.027 |
| DT \*S:G | \*\*\*  | 0.024  | 0.068  | NS  | 0.818  | 2.302  | NS  | 0.551  | 1.550  | \*\*\*  | 0.014 | 0.039 |
| DT\*GF  | \*\*\*  | 0.015  | 0.043  | NS  | 0.517  | 1.456  | \*\*  | 0.348  | 0.981  | \*\* \* | 0.009 | 0.025 |
| DT\*S:G \*GF  | \*\*\*  | 0.034  | 0.096  | NS  | 1.157  | 3.256  | NS  | 0.779  | 2.193  | NS  | 0.019 | 0.055 |
| CV (%)  |  | 0.689  |  |  | 2.561  |  |  | 2.201  |  |  | 1.072 |  |

‘\*\*\*’ significant at 1%, ‘\*\*’ significant at 5%, ‘\*’ significant at 10%, ‘NS’ not significant

Different drying temperatures (50, 60, 70, and 80°C) of dried pasta had a significant effect on TPC, TFC and AA (Table 5). TPC ranged from 62.65 to 88.86 mg gallic acid/100g on db, TFC ranged from 46.32 to 73.39 mg quercetin/100g on db, and AA ranged from 2.23 to 3.93% on db. Table 4 shows that TPC, TFC and AA decreased as the drying temperature increased from 50 to 80°C. At 50 and 60°C drying temperatures, these parameters showed slight differences. TPC, TFC, and AA decreased to 13.68% and 27.51%, 15.91% and 28.17%, and 16.32% and 34.86% at 70 and 80°C drying temperatures of garlic pasta, respectively. Heating at higher temperatures decreased the TPC in the onion varieties (Sharma et al., 2015). Different unit operations, such as boiling, frying, and roasting, could decrease the phenolic compounds from various plant sources. Most fruits and vegetables have glycoside linkages in their flavonoids as dimers and oligomers. Monomers are formed when glycoside linkages are hydrolyzed during thermal processing. The decrease in total flavonoids at higher temperatures could be attributed to the breakdown of flavonoids (Manach et al., 2004). The decrease in AA with drying is a complex phenomenon since it may be associated with thermal, chemical, and enzymatic processes that lead to the loss of numerous active compounds (Kamiloglu et al., 2016).

**3.4. Textural properties of uncooked and cooked garlic incorporated pasta**

**3.4.1. Uncooked garlic incorporated pasta**

The hardness and fracturability of uncooked pasta samples are presented in Figs 1 and 2. It was observed that the hardness of the uncooked pasta sample was significantly different at 1% level with all the selected sources of combination, but the fracturability of uncooked pasta sample was significantly differences at 1%, 5%, 10%, and 10% levels with semolina to garlic ratio (S:G), drying temperature (DT), S:G and garlic forms (GF), and DT and GF, respectively (Table 6). The hardness of uncooked pasta samples was found to increase with an increase in DT except at 50°C. At 50°C, starch, protein and insoluble fiber are not fully gelatinized, completely denatured and converted into soluble fiber. These simple compounds strengthen the pasta structure (Hooper et al., 2023). As the quantity of garlic forms increased to 1%, the hardness of the uncooked pasta increased and then decreased with increased to 2% garlic forms. Similar results were reported for the formulation of white pan bread with different proportions of garlic powder (Hong & Shin, 2008). The complexity of the pasta texture is also due to the characteristics of the raw material and the selection of the processing conditions (Marti et al., 2014).

**3.4.2. Cooked garlic incorporated pasta**

Determining the texture of cooked pasta can be a challenging task, as the composition of the uncooked pasta plays a crucial role. Cooked pasta is characterized by its firmness and not as stickiness or squishiness. Although sensory evaluation is the most accurate way to determine pasta quality, instrumental methods are mainly used since they are cost- and time-effective. So, textural parameters of cooked pasta, especially firmness and adhesiveness, are measured using a texture analyzer. Figs 3 and 4 illustrate the change in firmness and adhesiveness of different variability (DT, S:G ratio, and GF) of prepared pasta samples. Firmness and adhesiveness of cooked pasta ANOVA results suggested that there was significant interaction between the sources of parameters (DT, S:G ratio, and GF) at 1% and 5% levels (Table 6). The adhesiveness showed no significant differences with all the combined sources (DT, S:G ratio, and GF). The firmness of pasta is associated with the strength of the gluten network and the moisture content at the centre (Ogawa & Adachi, 2014). A large amount of garlic grits added to the pasta showed a more porous structure and lower moisture content at the centre. The firmness of cooked pasta was found to be higher at 60°C then dried at 50, 70, and 80°C. The quantity of the dried garlic forms and its quantity alsoaffect the firmness of cooked pasta. The higher firmness was found at 1.5% added garlic powder pasta dried at 60°C and lower at 2.0% added garlic grit dried at 80°C. The adhesiveness was found to be higher at 1.5% added garlic powder pasta dried at 70°C and lower at 2.0% added garlic grit dried at 80°C. The addition of garlic powder showed less effect than grit because garlic powder has more surface area (Landillon et al., 2008) and, hence, is readily mixed with semolina, which does not affect the formulation of the gluten network.



**Fig. 1. Hardness of garlic forms of prepared uncooked pasta dried at different temperatures**

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**Fig. 2. Fracturability of garlic forms of prepared uncooked pasta dried at different temperatures**

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**Fig. 3. Firmness of garlic forms prepared dried at different temperatures and cooked pasta**

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**Fig. 4. Adhesiveness of garlic forms of prepared dried at different temperatures and cooked pasta**

**Table 6. ANOVA for hardness, fracturability, firmness and adhesiveness of garlic forms of prepared pasta dried at different temperatures**

|  |  |  |
| --- | --- | --- |
| Source | Raw pasta | Cooked pasta |
| Hardness (N) | Fracturability (mm) | Firmness / Stickiness Rig (N) | Work of adhesion (g/s) |
| F-value | ±SEM | LSD | F-value | ±SEM | LSD | F-value | ±SEM | LSD | F-value | ± SEM | LSD |
| DT | \*\*\* | 0.336 | 0.946 | \*\* | 0.039 | 0.110 | \*\*\* | 0.052 | 0.148 | \*\*\* | 0.133 | 0.374 |
| S:G | \*\*\* | 0.376 | 1.057 | \*\*\* | 0.044 | 0.123 | \*\*\* | 0.059 | 0.165 | \*\*\* | 0.148 | 0.418 |
| GF | \*\*\* | 0.238 | 0.669 | NS | 0.028 | 0.078 | \*\*\* | 0.037 | 0.104 | \*\*\* | 0.094 | 0.264 |
| S:G \*GF | \*\*\* | 0.531 | 1.495 | \* | 0.062 | 0.175 | \*\*\* | 0.083 | 0.234 | \*\*\* | 0.210 | 0.591 |
| DT \*S:G | \*\*\* | 0.751 | 2.115 | NS | 0.088 | 0.247 | \*\*\* | 0.117 | 0.330 | \*\* | 0.297 | 0.835 |
| DT\*GF | \*\*\* | 0.475 | 1.337 | \* | 0.055 | 0.156 | \*\*\* | 0.074 | 0.209 | \*\*\* | 0.188 | 0.528 |
| DT\*S:G \*GF | \*\*\* | 1.063 | 2.991 | NS | 0.124 | 0.349 | \*\*\* | 0.166 | 0.467 | NS | 0.420 | 1.181 |
| CV (%)  |  | 9.227 |  |  | 4.117 |  |  | 12.555 |  |  | 26.991 |  |

‘\*\*\*’ significant at 1%, ‘\*\*’ significant at 5%, ‘\*’ significant at 10%, ‘NS’ not significant

**3.6. Cooking quality of garlic incorporated pasta dried at different temperatures**

Pasta cooking quality characteristics, namely optimum cooking time (OCT, min), water absorption (WA, %), swelling index (SI, %) and gruel loss (GL, %) were represented in Table 7. OCT was considered at the time to disappear the white core portion or achieve nearly 100% gelatinization of starch (Sozer et al., 2007). The OCT of pasta samples increased as the drying temperature (50°C to 80°C) and quantity of dried garlic (0.5% to 2.0%) increased but decreased with garlic grits instead of garlic powder compared to control pasta.

Water molecules absorbed during the cooking of pasta indicate the swelling index. SI and WA of the developed garlic pasta were increased with respect to control. These parameters increased with an increase in the amount of garlic forms (GF) and an increase in drying temperature from 50°C to 80°C. Garlic powder showed higher SI and WA than garlic grit, except garlic grit was added to pasta and dried at 80°C. This may be due to the garlic grit creating porosity, resulting in a weak gluten network structure. At higher temperatures (80°C), the structure of the pasta network decreases, thus resulting in a decrease in SI and WA.

The cooking loss of dried pasta is acceptable up to 8.0% (Dick & Youngs, 1988). A lower amount of GL was observed with increased garlic powder from 0.5% to 2.0% and dried at 60°C or 70°C (Table 7). Adding proper amounts of GF could help strengthen the gluten network during the dough preparation and garlic polysaccharide-degraded compounds, mainly fructose and oligofructose, to interact with semolina protein (Zhang et al., 2015). However, an excessive quantity of GF diluted the gluten network and weakened the gluten structure through the exposure of starch to some extent, thus resulting in an increased GL compared with that of 2.0% GF-added garlic pasta. Similar cooking loss results were reported for rye floor noodles incorporated with black garlic powder (Liu et al., 2018).

Table 8 shows the 3-way ANOVA factor, namely DT, S:G ratio, and GF on OCT, WA, SI, and GL cooking quality parameters, and was found to be significant at 1% level. The coefficient of variation (CV) for OCT, WA, SI and GL was estimated to be 0.626%, 2.960%, 3.080%, and 0.530%, respectively.

**Table 7. OCT, WA, SI, and GL of garlic forms of prepared pasta dried at different temperatures**

|  |  |
| --- | --- |
| Semolina: Garlic | Drying temperature and form of garlic |
| 50°C | 60°C | 70°C | 80°C |
| Powder | Grit | Powder | Grit | Powder | Grit | Powder | Grit |
| Optimum cooking time (min) |
| 100:0 | 6.45±0.05 | 6.45±0.05 | 7.07±0.03 | 7.07±0.03 | 7.18±0.06 | 7.18±0.06 | 7.27±0.03 | 7.27±0.03 |
| 99.5:0.5 | 6.58±0.03 | 6.41±0.05 | 7.10±0.05 | 6.43±0.03 | 7.22±0.06 | 6.33±0.03 | 7.33±0.08 | 6.38±0.03 |
| 99:1 | 6.55±0.05 | 6.33±0.03 | 7.16±0.04 | 6.36±0.02 | 7.25±0.05 | 6.30±0.05 | 7.48±0.03 | 6.35±0.03 |
| 98.5:1.5 | 6.58±0.03 | 6.30±0.05 | 7.17±0.03 | 6.35±0.02 | 7.34±0.09 | 6.28±0.03 | 7.47±0.03 | 6.28±0.04 |
| 98:2 | 6.59±0.01 | 6.24±0.04 | 7.15±0.05 | 6.33±0.04 | 7.40±0.05 | 6.24±0.03 | 7.50±0.03 | 6.22±0.03 |
| Water absorption (%) |
| 100:0 | 142.23±2.37 | 142.23±2.37 | 148.17±3.46 | 148.17±3.46 | 185.83±4.01 | 185.83±4.01 | 210.00±3.34 | 210.00±3.34 |
| 99.5:0.5 | 158.57±5.38 | 157.93±3.97 | 153.10±2.80 | 164.03±5.19 | 185.97±3.26 | 175.43±5.11 | 212.67±1.72 | 160.30±8.60 |
| 99:1 | 183.20±9.35 | 177.13±8.91 | 152.60±3.08 | 159.13±4.07 | 186.00±7.06 | 172.47±4.82 | 217.57±8.57 | 154.13±2.98 |
| 98.5:1.5 | 192.70±6.36 | 180.37±5.74 | 160.23±4.40 | 151.43±2.40 | 188.37±5.96 | 170.80±8.74 | 235.77±3.91 | 140.83±2.26 |
| 98:2 | 189.20±3.76 | 182.23±3.18 | 158.00±9.00 | 146.53±6.31 | 191.90±3.30 | 167.47±1.45 | 236.58±5.00 | 135.90±4.39 |
| Swelling index (%) |
| 100:0 | 183.95±4.97 | 183.95±4.97 | 188.04±5.36 | 188.04±5.36 | 195.07±3.71 | 195.07±3.71 | 206.76±6.63 | 206.76±6.63 |
| 99.5:0.5 | 193.05±4.95 | 186.18±5.48 | 202.95±6.61 | 200.73±7.25 | 202.55±9.77 | 197.06±6.83 | 211.72±9.96 | 181.25±8.24 |
| 99:1 | 207.85±7.42 | 201.49±8.89 | 218.37±6.07 | 214.27±7.52 | 215.86±4.42 | 199.92±1.02 | 217.64±6.51 | 164.74±5.80 |
| 98.5:1.5 | 235.33±4.20 | 224.37±6.27 | 225.66±7.99 | 220.31±7.60 | 219.05±2.78 | 201.95±6.93 | 223.40±5.22 | 156.79±4.52 |
| 98:2 | 290.15±9.17 | 239.32±5.24 | 233.50±4.64 | 228.19±8.73 | 221.32±5.27 | 203.70±5.77 | 221.08±3.90 | 152.98±6.67 |
| Gruel loss (%) |
| 100:0 | 8.25±0.08 | 8.25±0.08 | 7.82±0.05 | 7.82±0.05 | 7.82±0.02 | 7.82±0.02 | 7.86±0.05 | 7.86±0.05 |
| 99.5:0.5 | 8.25±0.03 | 8.32±0.04 | 7.71±0.04 | 8.18±0.04 | 7.70±0.02 | 8.06±0.03 | 7.82±0.03 | 8.23±0.06 |
| 99:1 | 8.23±0.04 | 8.41±0.02 | 7.64±0.04 | 8.29±0.03 | 7.63±0.06 | 8.20±0.05 | 7.79±0.07 | 8.28±0.03 |
| 98.5:1.5 | 8.19±0.04 | 8.45±0.04 | 7.58±0.02 | 8.33±0.04 | 7.57±0.02 | 8.31±0.04 | 7.75±0.05 | 8.35±0.05 |
| 98:2 | 8.11±0.05 | 8.52±0.02 | 7.55±0.02 | 8.42±0.03 | 7.54±0.03 | 8.40±0.05 | 7.73±0.05 | 8.40±0.03 |

**Table 8. ANOVA for optimum cooking time (OCT), water absorption (WA), swelling index (SI), and gruel loss (GL) of garlic forms of prepared pasta dried at different temperatures**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Source | Optimum cooking time(min) | Water absorption(%) | Swelling index(%) | Gruel loss(%) |
| F-value | M±SE | LSD | F-value | M±SE | LSD | F-value | M±SE | LSD | F-value | M±SE | LSD |
| DT | \*\*\* | 0.008 | 0.022 | \*\*\* | 0.942 | 2.651 | \*\*\* | 1.161 | 3.269 | \*\*\* | 0.008 | 0.022 |
| S:G | \*\*\* | 0.009 | 0.024 | \*\*\* | 1.053 | 2.963 | \*\*\* | 1.299 | 3.654 | \*\*\* | 0.009 | 0.024 |
| GF | \*\*\* | 0.005 | 0.015 | \*\*\* | 0.666 | 1.874 | \*\*\* | 0.821 | 2.311 | \*\*\* | 0.005 | 0.015 |
| S:G \*GF | \*\*\* | 0.012 | 0.034 | \*\*\* | 1.489 | 4.191 | \*\*\* | 1.836 | 5.168 | \*\*\* | 0.012 | 0.035 |
| DT \*S:G | \*\*\* | 0.017 | 0.049 | \*\*\* | 2.106 | 5.927 | \*\*\* | 2.597 | 7.309 | \*\* | 0.017 | 0.049 |
| DT\*GF | \*\*\* | 0.011 | 0.031 | \*\*\* | 1.332 | 3.749 | \*\*\* | 1.642 | 4.623 | \*\*\* | 0.011 | 0.031 |
| DT\*S:G \*GF | \*\*\* | 0.024 | 0.024 | \*\*\* | 2.978 | 8.382 | \*\*\* | 3.673 | 10.336 | \*\*\* | 0.025 | 0.069 |
| CV (%) |  | 0.626 |  |  | 2.960 |  |  | 3.080 |  |  | 0.530 |  |

‘\*\*\*’ significant at 1%, ‘\*\*’ significant at 5%, ‘\*’ significant at 10%, ‘NS’ not significant

**4. CONCLUSION**

The protein and ash content were significantly increased with an increase in the quantity of garlic, and no significant changes were observed in fat content in prepared pasta dried between 50-80ºC and forms of garlic (powder and grit). The allicin content was found to be in the ranges of 4.95 to 19.72 mg/100g for garlic powder and 4.95 to 19.73 mg/100g for garlic grit in incorporated pasta. The allicin content was decreased slightly between 50 and 60°C and losses higher 17.58-20.02% and 30.62-31.40% at 70 and 80°C, respectively, when added same quantity of dried garlic. TPC, TFC, and AA decreased 13.68% and 27.51%, 15.91% and 28.17%, and 16.32% and 34.86% at 70 and 80°C drying temperatures, respectively of the same quantity of garlic forms in the prepared pasta, but the negligible difference was observed at 50 and 60ºC in same condition. The firmness of cooked pasta was found to be higher at 60°C then dried at 50, 70, and 80°C. The higher firmness was found at 1.5% added garlic powder pasta dried at 60°C and lower at 2.0% added garlic grit dried at 80°C. The optimum cooking time of all the prepared pasta was less than 7.5 min, and gruel loss was found maximum at 50ºC dried temperature of prepared pasta. Based on the measured parameters the best garlic incorporated pasta was found better prepared with 1.5% garlic powder incorporated pasta and dried at 60°C.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**COMPETING INTERESTS**

Authors have declared that no competing interests exist.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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