***Original Research Article***

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

**ABSTRACT**

Pasta is one of the most demanding foods all over the world by all age groups, mainly made from durum wheat semolina and water, prepared by several unit operations. It provides carbohydrates as a major nutrient. Garlic is richest source of organosulfur compounds and rich in other major nutrients, namely phenols, flavonoids, proteins, and minerals. Nowadays, people are shifting towards functional instant foods prepared from natural sources with high nutritional value. Therefore, in this study aim to develop 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 showed 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 exhibited higher losses 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 differences were observed at lower temperatures (50 and 60ºC) under the same conditions. The optimum cooking time of pasta samples increased with an increase in 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 than when dried at 50, 70, and 80°C. The gruel loss was found to be maximum at the 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*

**Symbol**

HG-17 Haryana garlic-17

HEPS n-(2-hydroxyethyl)piperazine-n'-(2-ethanesulphonic acid

DTNB 5,5’-dithio-bis-(2-nitrobenzoic acid

DPPH 2,2-Diphenyl-1-picrylhydrazyl

AC Allicin content

TPC Total phenol content

TFC Total flavonoid content

AA Antioxidant activity

OCT Optimal cooking time

GL Gruel loss

WA Water absorption

SI Swelling index

S:G Semolina to garlic ratio

DT Drying temperature

GF Garlic forms

ANOVA Analysis of variance

**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 in-demand foods, mainly made from durum wheat semolina and water, prepared through several unit operations. It is primarily 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 shifting 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 present a novel approach to preparing pasta as a vehicle to deliver phytochemicals.

Considering garlic's natural and richest bioactive profile, it is unique among all other food products. It is mainly attributed to three groups of 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; accounting 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 (Prakash *et al*., 2024). Garlic is the richest source of organosulfur compounds (Prati *et al*., 2014) and the third major source of phenolic compounds (Prakash et al., 2023; Shekhar, Prakash, Singha, et al., 2023) among vegetables. Various researchers have mentioned that garlic has defensive properties against various ailments, namely cardiovascular diseases, diabetes, cancer, atherosclerosis, hypoglycaemia, microbial activity, antidote effects, hepatoprotective properties, and platelet aggregatory activity (El-Saber Batiha et al., 2020; Shekhar, Prakash, Shekhar, et al., 2023; Sobenin et al., 2010).

Garlic can be used in different forms, including paste, essential oil, aged garlic extract, black garlic, pickles, 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, decreased transportation costs, extended shelf life, and, most notably, versatile applications in the food and pharmaceutical industries as a functional ingredient for easy amalgamation behaviour (Demiray and Tulek, 2014). Researchers have attempted to develop processed products such as 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 garlic fortified pasta rich in phytochemicals. The research objective is also to determine the effect of drying at different temperatures onallicin, phenols, antioxidant properties, textural characteristics and cooking properties of prepared garlic-incorporated pasta. The present research has 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 the 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 obtained 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 recommended 0.4 to 1.2 g/day (Prati et al., 2014). The consumption of garlic per day as a dietary supplement was recommended to be between 600 and 900 mg by the American Dietetic Association, 2004 (Rana et al., 2011). Based on recommendations from various agencies, the garlic forms were considered to be between 0.0 and 2.0 g in this research. The pasta was prepared with semolina and garlic form (Grit or powder) and mixed thoroughly in a Hobart mixer (5KPM50, USA) for 5 minutes 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 lengths 2.5 to 2.8cm with an automatic knife cutter moving over the outer surface of the die. The freshly prepared Ziti-cut tubular pasta had a moisture content of about 28%. It was dehydrated in a static drier at present temperature of 50, 60, 70 and 80°C until reaching a constant weight (Gull et al., 2018). The dried pasta was separately stored in zip-lock pouches for further study. The control pasta (semolina : garlic form ratio equals to 100:0) was prepared without addition of dried garlic (power and grit) as per the above process. The treatment code of control pasta formulations are mentioned in Table 1 namely T0150, T0250, T0160, T0260, T0170, T0270, T0180 and T0280.

**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 as the difference between100 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 the 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 the 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 and 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 seconds 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 previously determined optimal cooking time (OCT). Immediately; it was cooled 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 (Gull et al., 2015). The textural properties of uncooked and cooked pasta were performed in triplicate.

**2.2.5. Cooking quality of pasta**

The OCT of pasta was determined (AACC, 2000). The cooking test was performed separately for individual pasta treatments to decide their OCT. Briefly; 300 ml (approximately) of boiling water was used to cook the 10.0 g of pasta. The OCT was considered upon the disappearance of the white core portion in the pasta after squeezing. Each pasta treatment sample was optimally cooked to the 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 until constant weight was achieved. The water absorption capacity of pasta was estimated using equation 1.

(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.

(2)

**2.2.6. Statistical analysis**

Analyzed parameters were performed three times and represented as arithmetic mean±standard deviation. Analysis of variance (ANOVA) of individual analyzed parameters was conducted using Minitab17 statistical software to determine 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 analysed 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 ratios (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 are represented in Table 3. The protein and ash content significantly increased with an increase in the quantity of garlic, while no significant changes were observed in the fat content of prepared pasta dried between 50-80ºC and in the forms of garlic (powder and grit). This may be due to the dried garlic contains higher amount of protein (25.83±0.40%) and ash (3.42±0.13%) content as compared to semolina i.e. 12.07±0.06% and 0.67±0.02 respectively.

**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). The ANOVA table of estimated parameters, namely AC, TPC, TFC, and AA, was presented at 1%, 5% and 10% significant levels with all sources of pasta combinations (Table 5). The AC, TPC, TFC, and AA were found to be 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 exhibiting cohesive 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, as well as excellent source of antioxidant activity (Feng et al., 2019).

AC in the garlic incorporated dried pasta (50, 60, 70 and 80°C) was found to decrease slightly between 50 and 60°C, while losses higher 17.58-20.02% and 30.62-31.40% at 70 and 80°C, respectively. The allicin content in pasta might degrade 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 of 75, 85, and 95°C exposure in heated-blended garlic and after blanching (5 min), the 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 it was 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 (mgGA/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. Uncookedgarlic incorporated pasta**

The hardness and fracturability of uncooked pasta samples are presented in Figs1 and 2. It was observed that the hardness of the uncooked pasta sample was significantly differentat the 1% level with all the selected sources of combination, but the fracturability of the uncooked pasta sample showed significant differences at the 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 the 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 an increase 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 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 rather than its 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 variables (DT, S:G ratio, and GF) of prepared pasta samples. ANOVA results for the firmness and adhesiveness of cooked pasta suggested that there was significant interaction between the sources of parameters (DT, S:G ratio, andGF) at the 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 resulted in a more porous structure and lower moisture content at the centre. The firmness of cooked pasta was found to be higher at 60°C than when dried at 50, 70, and 80°C. The quantity of the dried garlic forms and its amount also affect the firmness of cooked pasta. The highest firmness was found in pasta with 1.5% added garlic powder dried at 60°C, while the lowest was observed in pasta with 2.0% added garlic grit dried at 80°C. The adhesiveness was higher in pasta with 1.5% added garlic powder dried at 70°C and lower in pasta with 2.0% added garlic grit dried at 80°C. The addition of garlic powder showed less effect than grit because garlic powder has a greater 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. Number 1, 2, 3, 4 represent the drying temperature of prepared pasta at 50, 60, 70, and 80ºC, respectively, words A and B indicated the garlic forms added in the pasta formulation i.e. Powder and Grit, respectively and Roman number I, II, III, IV, and V represent the Semolina and Garlic ratio added in the pasta i.e. 100:0, 99.5:0.5, 99.0:1.0, 98.5:1.5, 98.0:2.0 (g/g) respectively.**

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**Fig.2. Fracturability of garlic forms of prepared uncooked pasta dried at different temperatures Number 1, 2, 3, 4 represent the drying temperature of prepared pasta at 50, 60, 70, and 80ºC, respectively, words A and B indicated the garlic forms added in the pasta formulation i.e. Powder and Grit, respectively and Roman number I, II, III, IV, and V represent the Semolina and Garlic ratio added in the pasta i.e. 100:0, 99.5:0.5, 99.0:1.0, 98.5:1.5, 98.0:2.0 (g/g) respectively.**

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**Fig.3. Firmness of garlic forms prepared dried at different temperatures and cooked pasta Number 1, 2, 3, 4 represent the drying temperature of prepared pasta at 50, 60, 70, and 80ºC, respectively, words A and B indicated the garlic forms added in the pasta formulation i.e. Powder and Grit, respectively and Roman number I, II, III, IV, and V represent the Semolina and Garlic ratio added in the pasta i.e. 100:0, 99.5:0.5, 99.0:1.0, 98.5:1.5, 98.0:2.0 (g/g) respectively.**

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**Fig.4. Adhesiveness of garlic forms of prepared dried at different temperatures and cooked pasta Number 1, 2, 3, 4 represent the drying temperature of prepared pasta at 50, 60, 70, and 80ºC, respectively, words A and B indicated the garlic forms added in the pasta formulation i.e. Powder and Grit, respectively and Roman number I, II, III, IV, and V represent the Semolina and Garlic ratio added in the pasta i.e. 100:0, 99.5:0.5, 99.0:1.0, 98.5:1.5, 98.0:2.0 (g/g) respectively.**

**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, %) are represented in Table 7. OCT is 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. This may be due to the garlic grit forms porous structure matrix in the pasta as compared to garlic powder.

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 when 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 factors, namely DT, S:G ratio, and GF on OCT, WA, SI, and GL cooking quality parameters, and they were found to be significant at the1% 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 significantly increased with an increase in the quantity of garlic, while 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 ranged from 4.95 to 19.72mg/100g for garlic powder and 4.95 to 19.73mg/100g for garlic grit in incorporated pasta. The allicin content decreased slightly between 50 and 60°C, with losses of17.58-20.02% and 30.62-31.40% at 70 and 80°C, respectively, when the same quantity of dried garlic was added. TPC, TFC, and AA decreased by 13.68% and 27.51%, 15.91% and 28.17%, and 16.32% and 34.86% at 70 and 80°C drying temperatures, respectively for the same quantity of garlic forms in the prepared pasta, but negligible differences were observed at 50 and 60ºC under the same conditions. The firmness of cooked pasta was higherat 60°C than at 50, 70, and 80°C. The highest firmness was found in 1.5% garlic powder pasta dried at 60°C, while the lowest was in 2.0% garlic grit dried at 80°C. The optimum cooking time for all the prepared pasta was less than 7.5 minutes, and gruel loss was maximum at the 50ºC dried temperature of prepared pasta. Based on the measured parameters the best garlic incorporated pasta was found to be the one prepared with 1.5% garlic powder 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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