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# QUALITY CHARACTERISTICS OF NOODLE FORTIFIED BY CHICKPEA OR LUPINE PROTEIN CONCENTRATES

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## ABSTRACT

Physicochemical, cooking quality and sensory characteristics of noodles fortified by chickpea or lupine protein concentrates (CPC or LPC, respectively) as a non-traditional protein sources were evaluated. The obtained data was analyzed by cubic polynomial regression trend. The optimum independent variables were determined by assumed the mathematical predictive models. Optimum cooking time was decreased significantly ($p<0.05$) with increasing the replacement levels. Cooking yield and swelling index of prepared noodles improved at predictive CPC or LPC levels were 10.74 or 5.07 %. The optimum predictive values were 247.9 and 290.3 %; 200.7 and 304.8 %, respectively. Cooking loss values of LPC noodles significantly ($p<0.05$) lower than the control sample at all concentrations. The CPC noodle had the same control sample cooking loss value at concentration 10.74 %. Each of redness and yellowness color parameters were enhanced in the CPC and LPC noodles. Non-essential and essential amino acids percent, calculated protein efficiency ratio, essential amino acid index, biological value, chemical score and limiting amino acids were improved. The noodles prepared by CPC or LPC concentrations until 20 or 15 %, respectively had a positive overall acceptability scores with non-significant ($p>0.05$) differences compared to the control sample.
**Keywords**: Noodle, Fortification, Chickpea, Lupine, Protein.

## INTRODUCTION

The major nutritional problem in most of the developing countries is protein-calorie malnutrition. This acute problem is, of course, due to factors such as high birth rates, increased population, insufficient agricultural products and limited supply of high quality proteins (El-Adawy, 1997). Therefore, looking for inexpensive high protein materials is considered an important task for scientists in these countries. Such materials will improve and enhance the nutritional quality of the diets and the health of the people. Noodles are very popular wheat foods made from common wheat flour, water and some additives (Sui *et al.*, 2006). Noodle contains 11-15 % proteins (dry basis) but, is deficient in lysine, common to most cereal products. A growing demand for functional plant proteins could be identified, which properties are customized for specific applications and formulations as food ingredients (Wäsche *et al.*, 2001). This provides an opportunity for the use of non-traditional raw materials to increase the nutritional quality like legumes and cereals are nutritionally complementary (Duranti, 2006; Chillo, *et al.*, 2008a,b).

Chickpea is the third important legume crop grown in at least 33 countries (Singh, 1997). Due to their good balance of amino acids, high protein bioavailability and relatively low levels of anti-nutritional factors, chickpea seeds have been considered a suitable source of dietary proteins (Newman, *et al.*, 1987). Chickpea is suitable source of proteins, complex carbohydrates, vitamins and minerals (Wang *et al.*, 2010). Chickpea seed has a high protein digestibility, contains high levels of complex carbohydrates, is rich in vitamins and minerals and is relatively free from anti-nutritional factors (Wood and Grusak, 2007). Lupine (*Lupines albus*), a member of the legume family, is a pea like plant cultivated all over the world (Postglione, 1983). Lupine is one of the most important crops in the world because of its nutritional quality. Seeds of various species of lupines have been used as food for over 3000 years around the Mediterranean (Longnecker, *et al.*, 1998). It is rich source of protein, complex carbohydrates, vitamins and minerals (Molina *et al.*, 2002; Wang *et al.*, 2010). Lupine flours can be an excellent choice to improve the nutritional value of wheat flours due to their potential to increase protein content (Hall and Johnson, 2004; Torres, *et al.*, 2006). Legumes have shown numerous health benefits (Chillo *et al.*, 2008a). Nutritional quality of protein depends on its essential amino acids composition. According to Singh, (1988), the problem of antinutritional factors in some seeds as chickpea and lupine could be overcome if the proteins are isolated. The nutritive value of plant proteins is known to be lower than that of animal protein. It is possible to improve the protein nutritional quality parameters as non-essential amino acid percent (NE/T %), essential amino acids percent (E/T %), protein efficiency ratio (C-PER), essential amino acids index (EAAI), Biological value (BV), Chemical score (CS) and limiting amino acid (LAA) by protein preparations replacement (Mahmoud, *et al.*, 2012).

This study was carried out to use the chickpea or lupine protein concentrates as a nontraditional protein sources to fortify the wheat flour. Preparation a high nutritional quality noodles by fortified wheat flour. Effect of replacement levels on noodle nutritional parameters, cooking quality and sensory characteristics were studied.

## MATERIALS AND METHODS

**Materials**

Wheat flour 72 % extraction, chickpea ((*Cicer arietinum* L.) and sweet lupine (*Lupinus angustifolius*) seeds were purchased from the local market, Cairo, Egypt.

**Preparation of protein concentrates**

Whole milled of chickpea and lupine seeds were prepared by grinding in Kenwood grinder (BL 335) until the grains could through a 300 µm sieve (Laboratory Test Sieve, Endecotts LTD. London, England). The whole milled of chickpea and lupine were defatted according to the procedure reported by Dervas *et al.*, (1999) using hexane (1:4 w/v). The slurry was kept with periodical stirring for 45 min, at ambient temperature and the hexane with fat was decanted. The fat extraction repeated twice and the defatted milled were dried in an air stream. Chickpea and lupine protein concentrates were prepared according to the Dev and Quensel (1988) procedure. Each defatted milled was washed 6 times with 70 % aqueous ethanol at a solid/liquid ratio of 1:10 (W/V). The protein concentrates were dried at room temperature (20 ºC ± 5) then, reground.

**Noodles preparation**

Noodles for control samples were prepared using 100 % wheat flour. Experimental samples were prepared using wheat flour replaced with equivalent portions of lupine or chickpea protein concentrate. The replacement concentrations were 5, 10, 15, 20 and 25 % based on solid contents. Noodle dough was prepared according to the procedure reported by Collins and Pangloli, (1997) on the basis 600g flour. All dry ingredients (wheat flour and lupine or chickpea protein concentrate) were combined and mixed to produce homogenize mixture. Placed the mixture in a mixing bowl and mixed until the dough formed. The dough was rounded (shaped into a ball), covered with plastic wrap, allowed to rest 30 min, hand-kneaded 1 min, divided into approximately 100-g portions and sheeted using pasta machine (Atlas 150 Well.AS.P, Italy) by rolling at position one and repeated at position three. Thereafter, the sheet of dough passed through a hand-operated pasta machine. Cut the dough into strips 5 mm wide, hanged on glass rods and air dried at 23–25 ºC for 4 hr. The air-dried noodles transferred to a cabinet dehydrator and dried to moisture content about 7 % at 70 ºC. Thereafter, cooled to room temperature, placed in plastic bags, sealed the plastic bags and stored at room temperature (20 ºC ± 5).

**Chemical analysis**

Moisture, ash, crud lipid and protein (N x 5.70) content was determined according to the AACC (2000).

**Cooking quality noodle**

Noodle cooking quality was determined according to the approved method in AACC, (2000). Optimum cooking time was the time required for the opaque central core of the noodles to disappear when squeezed gently between two glass plates after cooking. Twenty-five grams of noodles was cooked to optimum time in 300 ml tap water in a beaker, rinsed in cold water, and drained for 15 min before weighed. Percentage of increased weight calculated as a cooking yield. Solids content in the cooking water was determined by drying at 105°C ± 5 overnight. The cooking loss was expressed a percentage between the solid weight and initial dry matter. To calculate the swelling index divided the water displacement of cooked noodles by the water displacement of an equivalent amount of uncooked noodles.

**Amino acids composition and nutritional parameters**

Amino acids of the samples were determined according to the method reported in the Amino Acid Analyzer (LC 3000, USA) catalog. The nutritional values of wheat flour, chickpea protein concentrate (CPC) and lupine protein concentrate (LPC) calculated according to the specify equations. The proportion of essential amino acids (E) to the total amino acids (T) of the sample protein was calculated using Chavan, *et al.*, (2001) equation below:

$$\frac{E}{T}(\%) = \frac{\text{Sum of essential amino acids}}{\text{Sum of total essential amino acids}} \times 100 \qquad [1]$$

Calculated protein efficiency ratio (C-PER) were estimated according to the equation developed by Alsmeyer, *et al.*, (1974), as given below.

$$C-PER = -1.816 + 0.435\,(Met) + 0.780\,(Leu) + 0.211\,(His) - 0.944\,(Tyr) \qquad [2]$$

Essential amino acid index (EAAI) in relation to amino acid requirements of whole egg protein (Valine, 6.6; Methionine+Cystine, 5.7; Isoleucine, 5.4; leucine, 8.6; Phenylalanine+Tyrosine, 9.3; Lysine, 7.0; Threonine, 4.7) (Shils, *et al.*, 1998) was determined as described by Oser (1959) as follows:

$$EAAI = \sqrt[n]{\left(Ilu.\frac{P}{Ilu}.S\right) \times \left(Leu.\frac{P}{Leu}.S\right) \times \ldots \times (Phe.+Tyr.P/Phe.+Tyr.S)} \times 100$$

[3]

Where P, refers to the sample protein and S, refers to the standard protein.

Biological value (BV) was calculated according to the following equation as described by Oser (1959):

$$BV = (1.09 \times EAAI) - 11.73 \qquad [4]$$

Chemical score (CS) was calculated using the standard of amino acid requirement for an adult human (FAO/WHO, 1985) according to the follows equation:

$$CS = \left(\frac{Ai}{As}\right) \times 100 \qquad [5]$$

Where Ai, the amino acid in sample and As, the amino acid in standard

**Sensory evaluation**

Organoleptic properties of prepared noodles evaluated by ten members reference taste panel from staff of Food Science Department, Faculty of Agriculture, Ain Shams University according to the method reported by Szczesniak *et al.*, (1963). Color, texture, flavor and overall acceptability were evaluated according to a 1–9 scale, where 1 (extremely unpleasant) and 9 (extremely pleasant). Organoleptic properties of fortified noodles were evaluated compared with the control sample, which prepared from 100 % wheat flour.

**Statistical analysis**

Predicting individual Y was assumed by cubic polynomial regression model for the independent variables used regression analysis. The model proposed for response of Y reported by Montgomery (2001) as follows:

$Y= \beta_0 + \sum\beta_i X_i + \sum\beta_{ii} X_i + \sum\beta_{iii} X_i$ [6]

Where, $\beta_0$ , $\beta_i$ , $\beta_{ii}$ and $\beta_{iii}$ are intercept, linear, quadratic and cubic regression coefficient terms, respectively and Xi is independent variable. Analysis of variance was used to compare between means by Duncan multiple range at significance 5 %. Means with different letters are significantly different. Regression and ANOVA analysis were carrying out by Statistical Analysis System (SAS, 1996).

## RESULTS AND DISCUSSION

### Physicochemical characteristics

Proximate chemical composition (moisture, ash, lipid, protein), oil binding, water binding and color parameters of wheat flour, chickpea protein concentrate (CPC) and lupine protein concentrate (LPC) are present in Table (1). The moisture content in wheat flour was 13.43 % while significantly ($p<0.05$) decreased to 8.68 and 7.87 % in CPC and LPC, respectively. Ash content of CPC and LPC were 2.01 and 2.55 % which were significantly ($p<0.05$) higher than that of wheat flour. Wheat flour had the lowest lipid content (0.49 %) compared to those of CPC and CLP (1.04 and 0.89 %, respectively). Although the chickpea and lupine flour were extracted with hexane, lipids were not removed completely and parts of lipid were remained in protein concentrates and were associated with the protein (Sánchez-Vioque *et al.*, 1998[a]). These lipids, mainly of a polar nature (Sánchez-Vioque *et al.*, 1998[b]), play an important role in flavor (Rackis *et al.*, 1979) and in the interaction with proteins (Kikugawa *et al.*, 1981). The protein content of CPC and CLP (58.63 and 57.68 %) were significantly ($p<0.05$) higher than that in wheat flour (11.24 %). The protein content in CPC and CLP were increased versus extraction of the other components from the raw materials. Both water and oil binding capacity values were higher than that of wheat flour. The highest water binding capacity values was observed in CPC. In contrary the LPC had the highest oil binding capacity value. The obtained results were agreed with those of Aurelia *et al.*, (2009). Proteins forming a three-dimensional network structure to produce a matrix capable of holding significant amounts of water (Cano and Ancos, 2005). The presence of several non-polar side chains may bind the hydrocarbon chains of fats, thereby resulting in higher absorption of oil (Sathe *et al.*, 1982). Concerning the colorimetric parameters, the wheat flour had a significantly ($p<0.05$) higher brightness (L*) value (96.1), CPC and LPC came in the second and third order with values of 89.8 and 86.5, respectively. On contrary, the LPC had a higher redness (a*) and yellowness values -7.9 and 14.9, respectively, with significant difference ($P < 0.05$) than the CPC and wheat flour. The obtained results agreed with those of Mahmoud *et al.*, (2012).

**Table 1 Physicochemical characteristics of wheat flour, chickpea and lupine protein levels.**

| Samples | Moisture | Ash | Lipid | Protein (N x 5.7) | NFE* | Oil binding | Water binding | Colorimetric measurement | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | L* | a* | b* |
| Wheat flour | 13.43[a] ±0.66 | 0.57[b] ±0.13 | 0.49[b] ±0.13 | 11.24[b] ±0.16 | 74.14[a] ±0.62 | 125.0[c] ±6.9 | 113.0[c] ±1.2 | 96.1[a] ±0.01 | -11.7[c] ±0.12 | 5.4[c] ±0.03 |
| CPC | 8.68[b] ±0.82 | 2.01[a] ±0.20 | 1.04[a] ±0.09 | 58.63[a] ±0.88 | 29.60[b] ±1.98 | 146.0[b] ±1.8 | 325.0[a] ±2.2 | 89.8[b] ±0.01 | -9.5[b] ±0.04 | 10.5[b] ±0.43 |
| LPC | 7.87[b] ±0.52 | 2.55[a] ±0.29 | 0.89[a] ±0.04 | 57.68[a] ±1.62 | 30.90[b] ±0.85 | 162.5[a] ±0.9 | 235.0[b] ±1.1 | 86.5[c] ±0.00 | -7.9[a] ±0.01 | 14.9[a] ±0.00 |

**NFE, nitrogen free extract. *, calculated by difference. CPC, chickpea protein concentrate. LPC, lupine protein concentrate.**
**Means in the same column with different letters are significantly different (P<0.05).**
**Values are mean (n = 3) ± standard deviations.**

## Optimum cooking time

The optimum cooking times for prepared noodles are shown in Table (2). According to the obtained data, it emerged that the optimum cooking time (10.7 min.) of noodles was longer in the control sample than that of the prepared noodles using CPC. During pasta cooking, there is competition between starch and protein for water (Pagini, 1986). When less protein surrounds starch granules, they swell and gelatinize faster (Grzybowski and Donnlley, 1977) The optimum cooking time decreased significantly (p<0.05) with increasing the CPC concentration reached to the minimum cooking time 9.1 min at replacement concentration 25 %. The cooking times for CPC noodles were 10.8 and 10.5 min. at replacement concentrations 5 to 10 % with non-significant difference (p>0.05) compared to the control sample. Chillo *et al.*, (2008[a,b]) found that the optimum cooking time of durum spaghetti was longer than that of spaghetti in base quinoa, broad bean and chickpea flours. On the other hand, the different cooking time trend was observed for the LPC noodles. The cooking time was increased with increasing the LPC replacement concentrations till 15 % with a significant (p<0.05) differences compared to the control sample. Then, the cooking time was deceased till arrived to the minimum value (9.6 min) at replacement level of 25 %. This may be attributed to the change in the wheat starch gelation behavior. Starch granules lost integrity and formed a gel with soy protein isolate (Li *et al.*, 2007; Ribotta, *et al.*, 2007).

**Table 2 Optimum cooking time of prepared noodles using different levels of chickpea and lupine protein concentrates and regression coefficients of predicted cubic polynomial model.**

| Sample | Replacement concentrations (%) | | | | | | Regression coefficients parameters | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Linear | Quadratic | cubic | | | |
| | 0 (control) | 5 | 10 | 15 | 20 | 25 | a | $\beta_1$ | $\beta_2$ | $\beta_3$ | $R^2$ | C.V |
| CPC | 10.7[a] ±0.16 | 10.8[a] ±0.05 | 10.5[a] ±0.29 | 9.9[b] ±0.11 | 9.6[bc] ±0.18 | 9.1[c] ±0.17 | 10.7 | 0.064 | 0.011 | 0.00023 | 0.9921 | 2.10 |
| LPC | 10.7[bc] ±0.16 | 11.7[a] ±0.24 | 11.4[ab] ±0.56 | 10.8[bc] ±0.29 | 10.4[c] ±0.12 | 9.6[d] ±0.23 | 10.7 | 0.273 | 0.024 | 0.00047 | 0.9650 | 5.49 |

**CPC, chickpea protein concentrate. LPC, lupine protein concentrate.**
**Means in the same row with different letters are significantly different (P<0.05).**
**Values are mean (n = 3) ± standard deviations.**

Multiple regression coefficients are presented in Table (2) to predict the cooking time for CPC and LPC noodles by cubic polynomial models. The models were tested for adequacy by analysis of variance. The two regression models for CPC and LPC were highly significant (P<0.01) with $R^2$ = 0.9921 and 0.9650 moreover, CV= 2.10 and 5.49, respectively. The predicted models were reported as follows:

$$CPC\ cooking\ time = 10.7 + 0.064\mathrm{x} + 0.011\mathrm{x}^2 + 0.00023\mathrm{x}^3 \qquad [7]$$

$$LPC\ cooking\ time = 0.273 + 0.024\mathrm{x} + 0.00047\mathrm{x}^2 + 0.9650\mathrm{x}^3 \qquad [8]$$

**Cooking yield**

The obtained cooking yield values are presented in Figure (1). The cooking yield values improved by fortification the wheat flour by CPC at levels ranged between 5 to 20 %. The cooking yield increased with increasing the CPC level till the maximum value was 265.0 % at concentration 10 %. Then, the cooking yield arrived to the minimum value 203.4 % at concentration 25 %. On the other hand, used the LPC in noodles preparation produced noodles with cooking yield values higher than those prepared by CPC with significant differences (p<0.05). The noodle was prepared using 5 % LPC had higher cooking yield value (252 %) than the control sample 202.9 %. The noodles were prepared using LPC at level 10 % or higher were negatively affected. Generally, the noodles were prepared by 5, 10 % CPC and 5 % LPC gave cooking yield values higher than that sample prepared from 100 % wheat flour. The sample contain 10 % CPC came in the first order then, the samples contain 5 and 5 % CPC and LPC came in the second and third order, respectively. The obtained results agreed with the findings in table (1). However, the water binding capacity values for CPC and LPC were significantly (p<0.05) higher than that value for the wheat flour 72 % extraction rate. These increases due to the high protein content in the prepared protein concentrate. Duszkiewicz *et al.*, (1988); Bergman *et al.*,

(1994) observed high water absorption in spaghetti blended with legume protein concentrates compared to wheat pasta.

Effect of CPC or LPC concentrations on the cooking yield of prepared noodles was studied according to the polynomial cubic regression (Figure 1). The obtained predicted models are possible identify the optimum replacement concentrations required to give a high cooking yield. The predicted CPC or LPC concentrations were 10.74 and 5.07 % with predicted cooking yield were 247.9 and 200.7 %, respectively. The predicted models were as follows:

$$CPC\ cooking\ yield = 202.09 + 9.05x - 0.52x^2 + 0.0062x^3 \qquad [9]$$

$$LPC\ cooking\ yield = 209.8 - 2.43x + 0.1498x^2 - 0.0053x^3 \qquad [10]$$

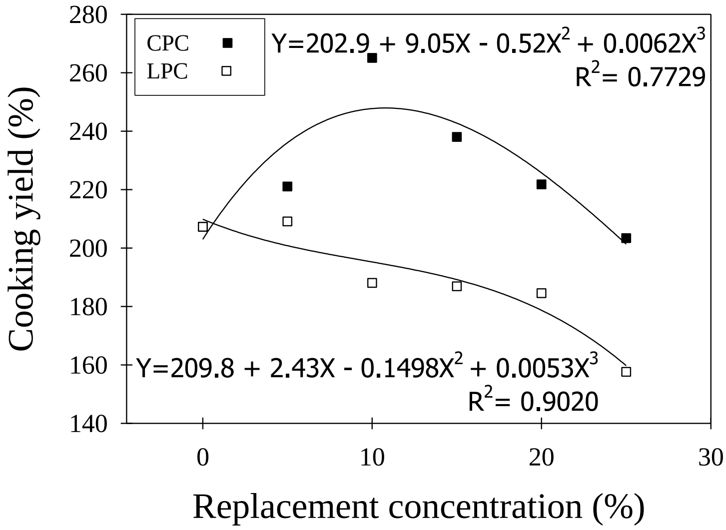


**Figure 1 Polynomial cubic trend of CPC or LPC replacement levels and the noodles cooking yield.**

**Swelling index**

The result in Figure (2) presented the swelling index for the different prepared noodle samples using CPC and PLC. Generally, the prepared noodles using CPC had swelling index values significantly ($p<0.05$) higher than those samples, which prepared using LPC. The prepared noodles using 5 and 10 % CPC had high swelling index values (328.1 and 284.4 %) with a significant difference ($P<0.05$) compared to the control sample that had a value 260.6 %. The swelling index values for noodle prepared using concentrations of 15, 20 or 25 % were significantly lower than the control sample. On the other hand, used the LPC at concentrations 5 and 10 % in preparation of noodles gave the same trend that observed with CPC noodles at the same replacement concentrations. The swelling index were 310.6 and 276.8 % at concentrations 5 and 10 %, respectively with a significant differences compared to the control sample. Increased the CPC or LPC replacement in prepared noodles more than 15 % performed to decreased the swelling index values with significant difference ($p<0.05$). Several authors reported that the water absorption capacity depend on the behavior of the proteins denaturation and the function of the amylose/amylopectin ratio and the chain length distribution of amylopectin (Enwere, *et al.*, 1998; Köber *et al.*, 2007).

The predictive swelling indices for CPC or LPC were expressed by the mathematical models at the CPC or LPC concentrations gave the highest cooking yield (10.74 and 5.07 %, respectively). The output data from the Polynomial cubic trend process expressed that the optimum swelling indices 290.3 and 304.8 %, respectively. The obtained perceptive swelling indices were significantly higher than that in control sample (267.5 %). The produced predictive equations were as follows:

$$CPC\ swelling\ index = 267.5 + 14.2\mathrm{x} - 1.58\mathrm{x}^2 + 0.038\mathrm{x}^3 \qquad [11]$$

$$LPC\ swelling\ index = 263.1 + 17.07\mathrm{x} - 1.99\mathrm{x}^2 + 0.049\mathrm{x}^3 \qquad [12]$$

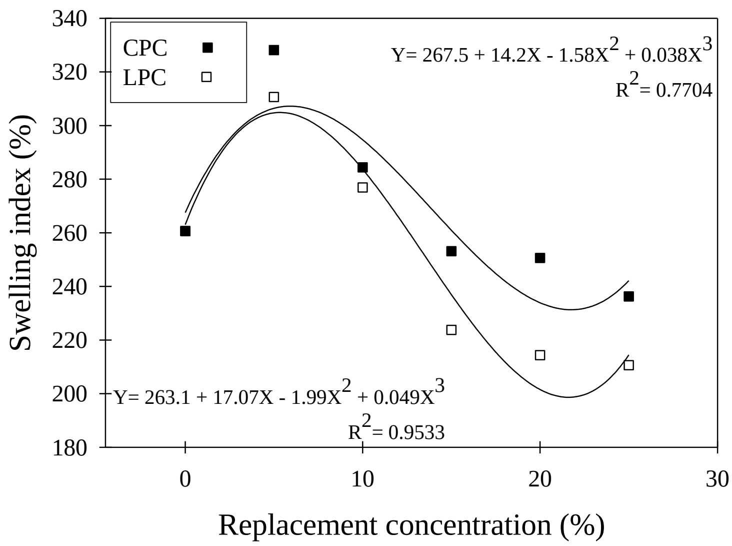


**Figure 2 Polynomial cubic trend of CPC or LPC replacement levels and the noodles swelling index.**

**Cooking loss**

The obtained cooking loss data for prepared noodles using CPC or LPC are shown in Figure (3). No significant differences ($p>0.05$) were observed either in the cooking loss values for the noodles prepared by 5, 10 and 15 % CPC or the control sample. The cooking loss values ranged between 5.7 to 5.9 % for the noodles prepared by 0 to 15 % CPC. Cooking loss significantly ($p<0.05$) gradually increased in the noodles prepared by CPC more than 15 %. Bergman *et al.*, (1994) mentioned to the high cooking loss in spaghetti blended with legume protein concentrates compared to wheat pasta. Savita *et al.*, (2013) reported that increasing the whey protein concentrates in the prepared pasta lead to increase the cooking loss. Walsh and Gills, (1971) stated that high protein content is related to high cooking loss. The highest cooking loss value was observed in the control sample 5.7 % compared to the noodles prepared by LPC. Replacement the wheat flour by LPC improved the noodles stability at different concentrations ranged between 5 to 25 %). The cooking losses at all replacement concentrations were lower than the cooking loss of control sample with significant difference ($p<0.05$) ranged between 4.7 to 5.4 %. The lowest cooking losses were observed at LPC replacement concentrations 10 and 15 %. Bergman *et al.* (1994) reported that the higher protein content in the noodles made from soft wheat flour and cowpea compared to soft wheat flour, might have provided a superior framework of denaturated protein that was better able to trap starch molecules, preventing their loss during cooking and thus ultimately decreasing cooking loss. During cooking, a weak or discontinuous protein matrix results in a protein network that is too loose and permits a greater amount of exudate to escape during starch granule gelatinization (Skrabanja and Kreft, 1998; Resmini and Pagani, 1983).

The regression models for obtained data for different CPC or LPC noodles were highly significant with $R^2$ = 0.7655 and 0.9924, respectively. The lowest predicted cooking loss values were 5.5 and 4.2 % at concentrations 5.07 and 11.7 %, respectively. The predictive equations were as follows:

$$CPC\ cooking\ loss = 5.65 - 0.04\mathrm{x} + 0.005\mathrm{x}^2 - 0.0001\mathrm{x}^3 \qquad [13]$$

$$LPC\ cooking\ loss = 5.73 - 0.027\mathrm{x} + 0.014\mathrm{x}^2 - 0.0001\mathrm{x}^3 \qquad [14]$$

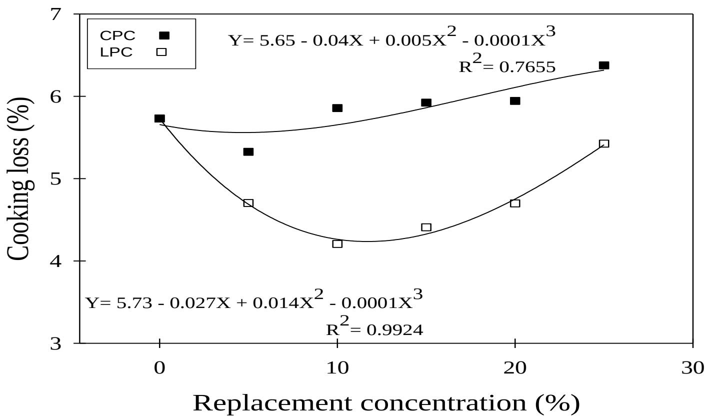


**Figure 3 Polynomial cubic trend of CPC or LPC replacement levels and the noodles cooking loss.**

## Color parameters

Color parameters of different prepared noodles were presented in Table (3). The brightness of the noodle sample which prepared by using 100 % wheat flour was 89.6. The L* (brightness) values of the CPC noodles were significantly ($P < 0.05$) lower than that of control sample at all used levels. The L* values ranged between 89.3 to 87.1 at concentrations ranged between 5 to 25 %. The brightness in LPC noodle was decreased significantly ($p<0.05$) from 88.9 at 5 % LPC to the minimum value (86.0) at 25 % LPC compared to the control sample.

**Table 3 Color parameters of prepared noodles using different protein levels of chickpea and lupine.**

| Replacement concentrations (%) | CPC noodles | | | LPC noodles | | |
|---|---|---|---|---|---|---|
| | L* | a* | b* | L* | a* | b* |
| 0 (control) | 89.6$^{a}$ ±0.03 | -10.9$^{a}$ ±0.24 | 8.3$^{e}$ ±0.03 | 89.6$^{a}$ ±0.03 | -10.9$^{e}$ ±0.24 | 8.3$^{f}$ ±0.03 |
| 5 | 89.3$^{b}$ ±0.02 | -10.8$^{a}$ ±0.18 | 10.9$^{d}$ ±0.01 | 88.9$^{b}$ ±0.01 | -10.0$^{d}$ ±0.18 | 12.2$^{e}$ ±0.04 |
| 10 | 88.6$^{c}$ ±0.02 | -10.6$^{a}$ ±0.19 | 11.5$^{c}$ ±0.02 | 88.3$^{c}$ ±0.03 | -9.6$^{c}$ ±0.26 | 12.6$^{d}$ ±0.03 |
| 15 | 87.8$^{d}$ ±0.26 | -10.6$^{a}$ ±0.39 | 11.9$^{bc}$ ±0.01 | 87.5$^{d}$ ±0.03 | -8.9$^{b}$ ±0.20 | 12.8$^{c}$ ±0.03 |
| 20 | 87.9$^{d}$ ±0.02 | -10.3$^{a}$ ±0.13 | 12.1$^{b}$ ±0.46 | 86.5$^{e}$ ±0.02 | -8.8$^{ab}$ ±0.16 | 14.1$^{b}$ ±0.04 |
| 25 | 87.1$^{e}$ ±0.02 | -9.9$^{a}$ ±0.33 | 13.6$^{a}$ ±0.48 | 86.0$^{f}$ ±0.03 | -8.5$^{a}$ ±0.10 | 14.7$^{a}$ ±0.3 |

**CPC, chickpea protein concentrate. LPC, lupine protein concentrate.**
**L*, brightness; a*, redness; b*, yellowness**
**Means in the same column with different letters are significantly different ($P<0.05$).**
**Values are mean (n = 3) ± standard deviations.**

Polynomial cubic trend of CPC or LPC replacement concentrations and the noodles color intensity was shown in Figure (4). Non-significant differences were observed between the control sample and all noodle samples prepared at all CPC replacement levels. Used the LPC in noodles preparation significantly ($p<0.05$) effected in the a* values at all concentrations. The a* was enhanced gradually with increasing the replacement concentration until arrived to – 8.5. Hou and Kruk, (1998) reported that the noodles with high values of L*, moderate b* for a slightly creamy, yellow color are desirable, while extremes on either side of the red, a*, scale are considered deleterious. On the other hand, the noodles prepared by either CPC or LPC had the same trend. the b* values increased from 10.9 and 12.2 at 5 % CPC or LPC respectively to 13.6 and 14.7 at 25 % CPC or LPC, respectively with a significant ($p<0.05$) differences compared to the control sample had 8.3.

The color intensity in different prepared noodle types slightly decreased Figure (4). According to the polynomial regression method the predictive models had a $R^2$= 0.9503 and 0.9940. the predictive models as flows:

$$\textit{CPC color intensity} = 90.7 - 0.007x - 0.008x^2 + 0.0002x^3 \quad [15]$$

$$\textit{LPC color intensity} = 90.6 - 0.048x - 0.006x^2 - 0.0001x^3 \quad [16]$$

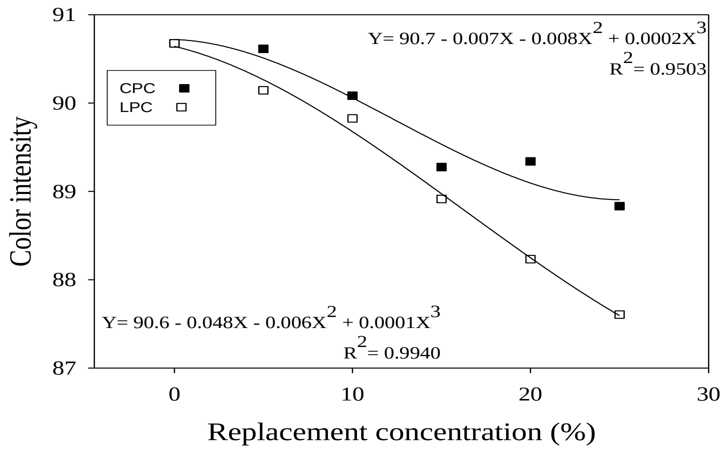


**Figure 4 Polynomial cubic trend of CPC or LPC replacement levels and the noodles color intensity.**

**Nutritional quality**

Data in Table (4) summarize the NE/T %, E/T %, C-PER, EAAI, BV, CS, LAA of wheat flour, CPC and their mixtures at 5, 10, 15, 20 and 25 %. Mixing wheat flour with CPC was significantly ($p<0.05$) improved the amino acid profile. According to the data in Table (4), it could be noticed that, the total essential amino acids increased significantly ($p<0.05$) with increasing the CPC replacement levels with decreasing in the total non-essential amino acids percentages. C-PER was increased to arrive the maximum values of 1.75 in the mixture of 75 % wheat and 25 % CPC. Wheat protein had the lowest C-PER value (1.13). EAAI was enhanced with replacement of CPC at different levels. EAAI ranged between, 61.3 in wheat flour protein to 74.9 in the wheat flour CPC mixture at maximum replacement concentration. In addition, the BV significantly ($p<0.05$) increased from 55.1 in wheat flour to values ranged between 61.5 and 70.0 in the different mixtures. Moreover, higher lysine content was associated with increasing in the biological value (Lampart-Szczapa *et al.*, 1997). However, the CS of wheat flour protein increased gradually from 29.8 % with increasing the CPC replacement level. The CS reached to the maximum value 90.1 % at the maximum replacement level. Although, the lysine was identifying as a limiting amino acid in wheat flour protein, nevertheless the lysine percent in the mixture was significantly ($p<0.05$) higher than those of wheat flour protein. The addition or substitution of raw materials rich in proteins results in pasta products with higher contents and better nutritional values than conventional semolina pasta (Marconi and Carcea, 2001).

**Table 4 Predicted of nutritional protein quality for wheat flour, chickpea protein level and their mixtures those used in noodles preparation.**

| Replaceme-nt concentrate-ons (%) | NE/T (%) | E/T (%) | C-PER | EAAI | BV | CS | LAA |
|---|---|---|---|---|---|---|---|
| 0 (control) | 66.3$^{a}$ ± 3.5 | 34.1$^{c}$ ± 2.8 | 1.13$^{e}$ ± 0.12 | 61.3$^{c}$ ± 5.6 | 55.1$^{c}$ ± 6.1 | 29.8 ± 4.4 | Lysine |
| 100 (CPC) | 56.3$^{c}$ ± 0.07 | 43.7$^{a}$ ± 0.7 | 2.11$^{a}$ ± 0.02 | 79.7$^{a}$ ± 1.1 | 75.2$^{a}$ ± 1.2 | 96.3 ± 4.2 | Valine |
| 5 | 64.1$^{ab}$ ± 2.9 | 36.2$^{bc}$ ± 2.3 | 1.34$^{d}$ ± 0.09 | 67.2$^{bc}$ ± 4.4 | 61.5$^{bc}$ ± 4.8 | 50.2 ± 3.9 | Lysine |
| 10 | 62.6$^{ab}$ ± 2.5 | 37.6$^{bc}$ ± 2.0 | 1.49$^{cd}$ ± 0.07 | 70.4$^{abc}$ ± 3.7 | 65.0$^{abc}$ ± 4.1 | 64.6 ± 3.5 | Lysine |
| 15 | 61.5$^{abc}$ ± 2.1 | 38.7$^{bc}$ ± 1.8 | 1.60$^{bc}$ ± 0.05 | 72.4$^{ab}$ ± 3.3 | 67.2$^{ab}$ ± 3.5 | 75.3 ± 3.2 | Lysine |
| 20 | 60.6$^{abc}$ ± 1.9 | 39.6$^{ab}$ ± 1.6 | 1.68$^{b}$ ± 0.04 | 73.9$^{ab}$ ± 2.9 | 68.8$^{ab}$ ± 3.1 | 83.5 ± 3.0 | Lysine |
| 25 | 60.0$^{abc}$ ± 1.7 | 40.2$^{ab}$ ± 1.4 | 1.75$^{b}$ ± 0.03 | 74.9$^{ab}$ ± 2.6 | 70.0$^{ab}$ ± 2.8 | 90.1 ± 2.8 | Lysine |

**NE/T (%), non-essential amino acids percent; E/T (%),essential amino acids percent; C-PER, calculated protein efficiency ratio; EAAI, essential amino acid index; BV, biological value; CS, chemical score; LAA, limiting amino acid.**
**CPC, chickpea protein concentrate.**
**Means in the same column with different letters are significantly different ($P<0.05$).**
**Values are mean (n = 3) ± standard deviations.**

The same trend was observed in the noodles prepared by replacement the wheat flour with different LPC concentrations. The protein quality parameters for prepared noodles were presented in Table (5). The E/T % was increased gradually from 34.1 % in wheat flour protein to 38.7 % in the 25 % wheat flour and 75 % LPC mixture. In the same time the NE/T % significantly ($p<0.05$) decreased from 66.3 % in wheat flour to values ranged between 64.7 to 61.5 % in the noodles prepared by LPC at concentrations ranged between 5 to 25 %, respectively. C-PER demonstrated the LPC as a good protein source with values of 2.02. The wheat flour classify as a poor protein source with the C-PER 1.13. The protein had a PER mor than 2 classified as a good protein sources (Satterlee, *et al.*, 1979). The C-PER was improved gradually with increasing the LPC replacement levels arrived to the maximum level of 1.71 at 25 % LPC with significant (p<0.05) difference compared to the control sample. The EAAI of LPC was higher than that in wheat flour with values being 77.5 and 61.3, respectively. The wheat flour exhibited lowest EAAI, 61.3 due to the decrease of majority of amino acids compared with the amino acid score pattern. Therefore, replace the wheat flour by LPC leads to significantly (p<0.5) increased the EAAI.

**Table 5 Predicted of nutritional protein quality for wheat flour, lupine protein level and their mixtures used in noodles preparation.**

| Replaceme-nt concentrate-ons (%) | NE/T (%) | E/T (%) | C-PER | EAAI | BV | CS | LAA |
|---|---|---|---|---|---|---|---|
| 0 (control) | $66.3^{a} \pm 3.5$ | $34.1^{b} \pm 2.8$ | $1.13^{e} \pm 0.12$ | $61.3^{c} \pm 5.6$ | $55.1^{c} \pm 6.1$ | $29.8 \pm 4.4$ | Lysine |
| 100 (LPC) | $58.6^{b} \pm 0.7$ | $41.3^{a} \pm 0.7$ | $2.02^{a} \pm 0.02$ | $77.5^{a} \pm 1.1$ | $72.8^{a} \pm 1.2$ | $96.1 \pm 4.2$ | Valine |
| 5 | $64.7^{a} \pm 2.9$ | $35.7^{b} \pm 2.3$ | $1.32^{d} \pm 0.09$ | $66.3^{bc} \pm 4.4$ | $60.6^{bc} \pm 4.8$ | $45.1 \pm 3.9$ | Lysine |
| 10 | $63.5^{ab} \pm 2.5$ | $36.8^{ab} \pm 2.0$ | $1.47^{cd} \pm 0.07$ | $69.1^{abc} \pm 3.7$ | $63.7^{abc} \pm 4.1$ | $55.9 \pm 3.5$ | Lysine |
| 15 | $62.7^{ab} \pm 2.1$ | $37.5^{ab} \pm 1.8$ | $1.57^{bc} \pm 0.05$ | $71.0^{ab} \pm 3.3$ | $65.7^{ab} \pm 3.5$ | $64.0 \pm 3.2$ | Lysine |
| 20 | $62.0^{ab} \pm 1.9$ | $38.2^{ab} \pm 1.6$ | $1.65^{b} \pm 0.04$ | $72.3^{ab} \pm 2.9$ | $67.1^{ab} \pm 3.1$ | $70.2 \pm 3.0$ | Lysine |
| 25 | $61.5^{ab} \pm 1.7$ | $38.7^{ab} \pm 1.4$ | $1.71^{b} \pm 0.03$ | $73.2^{ab} \pm 2.6$ | $68.2^{ab} \pm 2.8$ | $75.2 \pm 2.8$ | Lysine |

**NE/T (%), non-essential amino acids percent; E/T (%), essential amino acids percent; C-PER, calculated protein efficiency ratio; EAAI, essential amino acid index; BV, biological value; CS, chemical score; LAA, limiting amino acid.**
**LPC, lupine protein concentrate.**
**Means in the same column with different letters are significantly different (P<0.05).**
**Values are mean (n = 3) ± standard deviations.**

The improvement in EAAI values in the noodles prepared at different LPC concentrations lead to expect high calculated BV. Irrespective wheat flour, the BV increased with increasing the LPC level till reached to the maximum level 68.2 in the mixture contain 25 % wheat flour and 25 % LPC. BV of wheat flour realized downward pattern being 55.1. Balanced amino acid composition, particularly the contents of lysine, sulfur-containing amino acids are equivalent to those prepared by FAO/WHO for reference protein (Salunkhe, *et al.*, 1992). The deficient in lysine reduced the CS in the wheat flour to the minimal level 29.8. On the other hand, the LPC was deficient in Valine with CS 96.1. Added LPC to the wheat flour lead to increase the CS of the lysine form 29.8 to 75.2 in the mixture contain 75 % wheat flour and 25 % LPC. Incorporation of the lupine flour to semolina improved considerably the protein quality of pasta (Torres, *et al.*, 2007; Martínez-Villaluenga, *et al.*, 2010).

**Sensory evaluation**

According to Figure (5), the color of noodle samples prepared by CPC was not significantly (p>0.05) affected. No significant (p<0.05) differences were observed in color mean values between the noodle samples prepared using CPC levels 5, 10 and 15 % compared to the control sample. With increasing the replacement levels the prepared noodles had a color scores significantly lower than those of the control sample. Dry spaghetti color is an important quality factor for consumers (Rayas-Duarte *et al.*, 1996). Samples with more bean flour were darker (Shelke, 2006). Till 15 % CPC replacement the texture was improved and arrived to the highest score 6.2 compared to the control sample with a significant differences ($p<0.05$). The noodle samples prepared by 10 and 15 % LPC had the highest texture scores, 7.0 and 6.4, respectively with a significant differences compared with the control sample. With increasing the LPC concentration more than 15 % the texture was break down. The texture decreased as a function of the bean flour percentage (Gallegos-Infante, *et al.*, 2010). Replacement the wheat flour by CPC improved the prepared noodles flavor at all concentrations ranged from 5 to 25 % with significant differences compared to the control sample. No significant ($p>0.05$) differences between noodle samples prepared by 5, 10 or 15 % LPC and that control sample. The obtained overall acceptability appear the possibility use until 20 % of CPC to prepare the noodle with non-significant difference ($p>0.05$) with the control sample. In the same time it can be use LPC until 15 % in noodle preparation. The Sensory evaluation studies indicated that various forms of lupine can be used satisfactorily as a food ingredient in a wide range of foods (Dervas, *et al.*, 1999). The results obtained are in accordance with Sisson, *et al.*, (2005) and Chillo, *et al.*, 2008[b] they found that pasta stickiness decreased with increasing protein content.

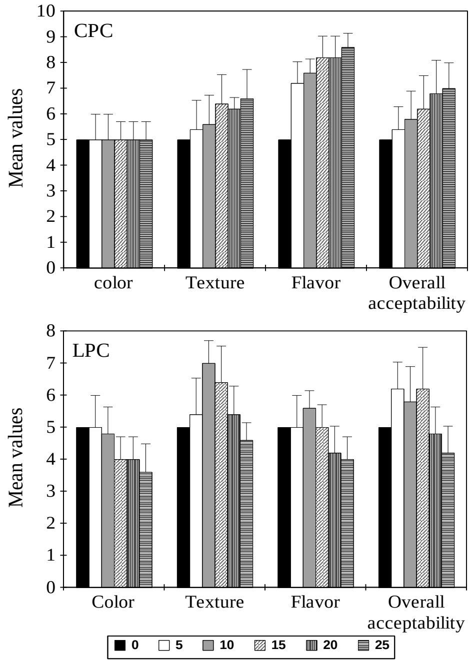


**Figure 5 Sensory evaluation of noodle prepared by different CPC or LPC ; levels (0, 5, 10, 15, 20 and 25 %).**

**Conclusion**

CPC or LPC can be used as a non-traditional protein sources to improve the noodle nutritional quality. According to the polynomial cubic models, the optimum predictive CPC and LPC levels were10.74 and 5.07 %, respectively. The noodles prepared at those concentrations gave cooking quality parameters higher than in the control sample. In the same time the noodles protein quality parameters were enhanced by added the different protein sources to the wheat flour. The lightness was slightly affected in the noodles prepared by CPC or LPC although, the redness and yellowness were improved. Overall acceptability of prepared noodles at concentrations until 20 or 15 % CPC or LPC, respectively had a high scores with non-significant differences compared to the control sample.

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## خصائص جودة النودلز المدعمة بالمركزات البروتينية للحمص أو الترمس

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تم تقييم الخصائص الكيموفيزيقية، جودة الطبخ والخواص الحسية للنودلز المدعمة بالمركزات البروتينية للحمص أو الترمس كمصادر بروتينية غير تقليدية. وقد تم إستنباط نماذج رياضية تنبؤية لدراسة تحليل الإنحدار التكعيبى للنتائج المتحصل عليها. وقد وجد أن زمن الطبخ قد انخفض معنويا ($p<0.05$) بزيادة نسبة إستبدال دقيق القمح بالمركزات البروتينية المحضرة. كما تحسن كل من الزيادة بعد الطبخ ومعامل الإنتفاخ معنويا ($p<0.05$) وكانت التركيزات الناتجة من النماذج الرياضية التنبؤية ١٠,٧٤ و ٥,٠٧ % لكل من الحمص والترمس على الترتيب. وكانت قيم الزيادة بعد الطبخ ٢٤٧,٩ و ٢٩٠,٣ % ، ومعامل الإنتفاخ ٢٠٠,٧ و ٣٠٤,٨ % لكل من النودل المحضرة بالمركزات البروتينية للحمص والترمس على الترتيب. كانت قيم فقد الطبخ لعينات النودل المحضرة بمركز بروتين الترمس عند كل التركيزات أقل معنويا ($p<0.05$) من قيمته فى عينة المقارنة. بينما لم يكن هناك فرق معنوى ($p>0.05$) بين عينة النودلز المحضرة من مركز بروتين الحمص عند التركيز المتوقع ١٠,٧٤ % وعينة المقارنة. تحسنت عوامل اللون (درجة الإحمرار والإصفرار) بزيادة نسبة المركزات البروتينية للحمص والترمس فى عينات النودلز المحضرة. كما أدى إستبدال دقيق القمح بالمركزات البروتينية للحمص والترمس إلى رفع قيم عوامل جودة البروتين للنودلز المحضرة مثل انخفاض نسبة الأحماض الأمينية غير الأساسية ومن ثم إرتفاع نسبة الأحماض الأمينية الأساسية، كذلك تحسن نسبة كفاءة البروتين المحسوبة، معامل الأحماض الأمينية الأساسية، القيمة الحيوية، المعامل الكيميائى والحمض الأمينى المحدد. ولم يكن هناك فروق معنوية ($p>0.05$) بين قيم القبول الحسى العام بين عينات النودل المحضرة بمركز بروتين الحمص حتى ٢٠ % ومركز بروتين الترمس حتى ١٥ % وقيمة القبول الحسى لعينة المقارنة.

**قام بتحكيم البحث**

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