

# Shelf Life Stability of Spaghetti Fortified with Legume Flours and Protein Concentrates<sup>1</sup>

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## ABSTRACT

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Durum wheat semolina (containing 3% [w/w] vital gluten) was fortified with 10% (w/w) of legume (navy and pinto) flours or their protein concentrates and extruded into spaghetti. Shelf life stability of the fortified spaghetti was evaluated at zero, one, three, and six months for quality parameters such as shattering, cooking quality, sensory evaluation, acidity, moisture, and color score. No shattering was observed during storage. Weight of cooked spaghetti was lower for fortified samples during storage. Samples with navy bean flours and concentrates had higher water

absorption. Cooking loss was the highest for spaghetti made of semolina-legume blends immediately after processing. Spaghetti containing legume flours and concentrates had higher firmness in comparison with controls during storage. Spaghetti fortified with legume flours and navy products was preferred by panelists over that fortified with legume protein concentrates. Acidity of spaghetti increased upon storage, especially for spaghetti with legume protein concentrates. Spaghetti with navy and pinto bean products had lower moisture content and color scores than controls.

Legumes recently have received great attention as a rich source of protein and calories. Much research has focused on ways to increase their utilization in human nutrition (D'Appolonia 1978, Jeffers et al 1979, Spink et al 1984). Adding legume flours or their protein concentrates to widely consumed pasta products seems to be one of the most economical methods. Because the amino acid compositions of legumes and cereals are complementary, fortification of pasta with legume protein increases its nutritional value. Several researchers (Lorenz et al 1979, Nielsen et al 1980) indicated that the addition of certain levels of legume flours or concentrates to pasta products gives acceptable results in terms of cooking quality and sensory evaluation.

This work is a continuation of previous studies on the utilization of edible legumes in pasta products (Bahnassey et al 1986, Bahnassey and Khan 1986). The purpose of this study was to evaluate the shelf life stability of spaghetti fortified with 10% navy bean flour or concentrate, or 10% pinto bean flour or concentrate, in comparison with spaghetti made of semolina and semolina with added vital gluten.

## MATERIALS AND METHODS

### Legume Samples

Two legumes, navy bean and pinto bean (*Phaseolus vulgaris*) were studied. Navy and pinto bean flours were prepared according to procedures described by Bahnassey (1984) and Bahnassey et al (1986). Legume protein concentrates were obtained by alkali extraction of navy or pinto bean flours with NaOH as proposed by Sosulski and Fan (1974).

### Durum Semolina

A commercial semolina sample of the durum wheat variety Vic, a strong gluten type, was obtained from the North Dakota State Mill, Grand Forks, ND.

### Preparation of Blends

Durum semolina (Vic) was blended with navy or pinto bean flour or their concentrates at 10% (w/w) levels, respectively. Vital wheat gluten (3%, w/w) was added to all fortified samples as well as

to control no. 2 (semolina plus gluten). Control no. 1 was 100% semolina.

### Spaghetti Processing and Storage Conditions

Spaghetti was prepared according to the method of Vasiljevic and Banasik (1980). After processing, 100-g samples of spaghetti were packaged in plastic bags, stored in a drawer at room temperature (approximately 23°C) and analyzed after zero, one, three, and six months. Samples were transferred periodically from one place to another to simulate handling conditions. No cracking or shattering was observed in any of the samples during the storage period. A shattering problem reported by Bahnassey et al (1986) seemed to have resulted from very low moisture content of their spaghetti but not from addition of legume flours or concentrates.

Moisture and protein contents were determined according to AACC methods 44-15A and 46-11 (AACC 1983), respectively.

### Spaghetti Color

The color of spaghetti was measured with a HunterLab color difference meter (model D 25M-9, Hunter Associates Laboratory, Inc., Reston, VA) as described by Walsh et al (1969).

### Acidity of Spaghetti

Ten grams of ground spaghetti were weighed into a 250-ml beaker and mixed with 100 ml of 67% (v/v) aqueous ethanol. Samples were titrated, after filtration with 0.1N NaOH, with phenolphthalein as an indicator (Gazette of SFRJ 1985).

### Quality Evaluation of Spaghetti

The cooking quality of spaghetti was determined according to Vasiljevic and Banasik (1980). Cooked weight was tested by weighing the spaghetti after draining for 2.5 min in a Buchner funnel. Cooking loss was determined by collecting the cooking and rinse waters in a preweighed glass beaker. Beakers were placed in an air oven at 100°C and the water evaporated to dryness. The weight of residue was reported as a percentage of dry spaghetti.

Spaghetti firmness was measured by shearing two strands of cooked spaghetti at a 90° angle with a special Plexiglas cutting tooth as described by Walsh (1971). An Instron universal tester, (type Tm-M, Instron model G90-21) was used for recording the amount of work required to shear the two strands of cooked spaghetti. Three replications were done for each sample; firmness score was calculated according to the procedure of Vasiljevic and Banasik (1980).

### Sensory Evaluation

Samples of spaghetti for sensory evaluation were cooked to optimum cooking time, drained, and served to panelists. Evaluations were made twice in the same day. Panelists, using a hedonic scale of 1 to 7 (with 7 being excellent and 1 being very poor) judged the following parameters: color, mouthfeel, external appearance, and general acceptability (Bahnassey and Khan 1986).

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## Statistical Analysis

The Statistical Analysis System (SAS Institute 1982) was used to analyze the data (cooking quality, sensory evaluation, moisture content, and acidity) of this study.

## RESULTS AND DISCUSSION

### Quality Evaluation of Spaghetti

The quality of spaghetti was evaluated by cooked weight, cooking loss, and firmness for all samples at optimum cooking time, and at 5 and 10 min beyond optimum cooking time. All analyses were done in duplicate immediately after processing (zero time) and after storage for one, three, and six months.

Results, presented in Table I, indicated that the cooked weights of the controls were not significantly different from each other during the entire storage period. However, the cooked weight of spaghetti fortified with legume flour or concentrates was lower than that of both controls. At the same time significant differences were noted between samples containing flours and concentrates. Similar results were reported by Breen et al (1977) and Bahnassey (1984). Several authors have observed that addition of legumes caused lower water absorption of fortified pasta products. Among the legumes, differences were significant. For example, spaghetti fortified with navy bean products had a higher cooked weight than that made with pinto bean products.

Cooking loss of spaghetti made of semolina-legume blends was higher than both controls (nos. 1 and 2) but only immediately after processing. After one month of storage, spaghetti with navy bean flour or concentrate showed significantly lower cooking loss, whereas significant differences were not detected among the pinto bean blends. A similar tendency was observed after three and six months. A significant decrease in cooking loss was also noted for spaghetti made of pure semolina although to a less pronounced degree. Vital wheat gluten added to semolina (control no. 2) seemed to lower cooking loss as storage time increased. Spaghetti made of legume flours generally showed a tendency to have slightly higher cooking losses than controls, whereas those made with legume concentrates had significantly lower cooking losses than the controls as storage progressed (at three and six months).

Spaghetti containing legume flours or concentrates had higher firmness scores than the controls. No significant differences were detected between controls themselves, with an exception after three months of storage. Also, no significant differences were

observed over time for spaghetti fortified with either legume flours or concentrates. The firmness score of spaghetti made with legume protein concentrates was the highest, followed by that made with legume flour and finally both controls. Differences among controls, flours, and concentrate samples were significant at all storage times.

Cooking time had a significant effect on cooked weight, cooking loss, and firmness. It is well established that the longer the cooking time, the higher the cooked weight and cooking loss but the lower the firmness. Our results are in agreement with this tendency and were not unexpected.

### Sensory Evaluation

A comparison of means for all data on sensory evaluation is shown in Table II.

### Legume Effect

Panel members gave the best scores for both controls (without significant differences between them) for all sensory parameters during the storage time evaluated. Spaghetti fortified with navy bean products was generally preferred by the panelists over pinto bean products; however, during storage time the differences were not always significant. Color and external appearance of spaghetti containing pinto bean flour and concentrate changed significantly as storage time progressed to three and six months. Mouthfeel and general acceptability of fortified spaghetti did not change appreciably for navy and pinto products during storage.

### Flour Effect

The data in Table II show that spaghetti fortified with legume flours was preferred over spaghetti with legume protein concentrates for all sensory parameters. No significant differences were detected between spaghetti containing concentrates and flour for mouthfeel at zero time and after six months of storage and for external appearance and general acceptability after three months. All the other scores were significantly lower for samples with concentrates compared with flour. Spaghetti made of semolina and semolina plus vital gluten (controls) obtained the best scores and were significantly better than the legume-fortified samples. The results of sensory evaluation indicated that the use of legume flours to fortify spaghetti is preferable to the use of legume protein concentrates. Navy bean products were more acceptable than pinto products. It should be noted that storage time did not influence the preferences of the panelists.

TABLE I  
Duncan's Multiple Range Test for Different Quality Parameters of Cooked Spaghetti  
Made of Semolina-Legume Blends After Various Storage Times

| Variable                                 | Cooked Weight <sup>a</sup> (g)<br>After Storage (months) |         |         |         | Cooking Loss (%)<br>After Storage (months) |        |         |        | Firmness (g·cm)<br>After Storage (months) |        |        |        |
|--|--|---------|---------|---------|--|--------|---------|--------|---|--------|--------|--------|
|  | 0  | 1       | 3       | 6       | 0  | 1      | 3       | 6      | 0   | 1      | 3      | 6      |
| Legume effect                            |  |         |         |         |  |        |         |        |   |        |        |        |
| Control no. 1                            | 30.83 a  | 30.65 a | 31.61 a | 32.61 a | 7.33 b                                     | 6.85 a | 7.02 a  | 6.80 a | 6.22 b                                    | 6.91 b | 6.54 c | 6.89 b |
| Control no. 2                            | 30.35 a  | 30.98 a | 30.88 a | 32.80 a | 7.43 b                                     | 6.78 a | 6.68 cb | 6.52 b | 6.40 b                                    | 7.00 b | 7.17 b | 7.08 b |
| Spaghetti with<br>NF and NC <sup>b</sup> | 29.85 ab   | 29.30 b | 29.93 b | 30.81 b | 7.55 ab                                    | 6.45 b | 6.63 c  | 6.45 b | 7.92 a                                    | 7.93 a | 8.46 a | 8.29 a |
| Spaghetti with<br>PF and PC              | 29.25 b  | 28.84 b | 29.69 b | 30.23 b | 7.88 a                                     | 6.79 a | 6.98 ab | 6.49 b | 7.81 a                                    | 7.74 a | 8.12 a | 8.40 a |
| Flour effect                             |  |         |         |         |  |        |         |        |   |        |        |        |
| Control no. 1<br>and no. 2               | 30.59 a  | 30.81 a | 31.25 a | 32.71 a | 7.38 b                                     | 6.81 a | 6.85 ab | 6.66 a | 6.31 c                                    | 6.96 c | 6.85 c | 6.99 c |
| Spaghetti with<br>NF and PF              | 30.18 a  | 29.70 b | 30.62 a | 31.29 b | 7.88 a                                     | 6.64 a | 6.98 a  | 6.83 a | 7.60 b                                    | 7.66 b | 8.04 b | 7.98 b |
| Spaghetti with<br>NC and PC              | 28.93 b  | 28.45 c | 28.99 b | 29.75 c | 7.55 b                                     | 6.60 a | 6.63 b  | 6.26 b | 8.13 a                                    | 8.00 a | 8.53 a | 8.71 a |
| Cooking time effect                      |  |         |         |         |  |        |         |        |   |        |        |        |
| Optimum                                  | 26.07 c  | 26.08 c | 26.34 c | 27.45 c | 6.53 c                                     | 5.56 c | 5.71 c  | 5.43 c | 8.17 a                                    | 8.33 a | 9.00 a | 8.99 a |
| 5 min over optimum                       | 30.17 b  | 29.80 b | 30.56 b | 31.55 b | 7.83 b                                     | 7.05 b | 6.98 b  | 6.54   | 7.32 b                                    | 7.63 b | 7.66 b | 7.83 b |
| 10 min over optimum                      | 33.45 a  | 33.80 a | 33.97 a | 34.74 a | 8.46 a                                     | 7.45 a | 7.78 a  | 7.63 a | 6.55 c                                    | 6.65 c | 6.76 c | 6.86 c |

<sup>a</sup>Means having the same letter in columns are not significantly different ( $\alpha = 0.05$ ).

<sup>b</sup>NF = navy bean flour, NC = navy bean protein concentrate, PF = pinto bean flour, and PC = pinto bean protein concentrate.

### Acidity, Moisture, and Color Analyses

Duncan's multiple range test for acidity, moisture, and color score of spaghetti after different storage times is presented in Table III.

Acidity of fortified spaghetti was higher than and significantly different from both controls. The differences between both controls were not significant up to one month of storage. However, after three and six months, acidity of spaghetti containing vital gluten (control no. 2) was significantly higher than spaghetti made of 100% semolina (control no. 1). The highest acidity was noted for the spaghetti with legume protein concentrates. During storage, acidity levels of spaghetti controls and those with legume flours changed and in all cases showed higher levels of acidity than at zero time.

Moisture content varied (significantly or not) depending on time and type of additives. Generally, spaghetti with navy and pinto

bean products had lower moisture content than controls. Spaghetti made of 100% semolina had slightly higher moisture than that with vital gluten (control no. 2) which indicates that vital gluten, to some extent, accelerates moisture loss. Samples of spaghetti fortified with legume concentrates showed lower moisture content up to three months of storage. After six months of storage, spaghetti with legume flours had the lowest moisture, while no significant differences were detected between controls and spaghetti with concentrates.

Color score of control samples was significantly better than for those fortified with navy or pinto products. During storage time there were no differences between controls (nos. 1 and 2) themselves. Spaghetti fortified with navy and pinto products had similar scores at zero time and after three months of storage, whereas after one and six months, the differences between them were significant. Neither spaghetti with legume flours nor with

**TABLE II**  
Duncan's Multiple Range Test for Sensory Evaluation of Spaghetti made of Semolina-Legume Blends After Different Storage Times

| Variable/<br>Storage Time<br>(months) | Legume Effect <sup>a</sup> |               |  |  | Flour Effect <sup>a</sup> |                             |                             |
|---------------------------------------|----------------------------|---------------|--|--|---------------------------|-----------------------------|-----------------------------|
|                                       | Control No. 1              | Control No. 2 | Spaghetti<br>with NF and NC <sup>b</sup> | Spaghetti<br>with PF and PC <sup>c</sup> | Control<br>Nos. 1 and 2   | Spaghetti<br>with NF and PF | Spaghetti<br>with NC and PC |
| <b>Color</b>                          |                            |               |  |  |                           |                             |                             |
| 0                                     | 31.50 a <sup>d</sup>       | 30.50 a       | 22.25 b                                  | 19.00 b                                  | 31.00 a                   | 23.00 b                     | 18.25 c                     |
| 1                                     | 31.00 a                    | 29.50 a       | 20.50 b                                  | 17.25 b                                  | 30.25 a                   | 20.00 b                     | 17.75 c                     |
| 3                                     | 32.50 a                    | 31.00 a       | 25.25 b                                  | 18.00 c                                  | 31.75 a                   | 23.50 b                     | 19.75 c                     |
| 6                                     | 33.00 a                    | 33.00 a       | 23.75 b                                  | 19.25 c                                  | 33.00 a                   | 24.00 b                     | 19.00 c                     |
| <b>Mouthfeel</b>                      |                            |               |  |  |                           |                             |                             |
| 0                                     | 28.50 a                    | 30.00 a       | 19.75 b                                  | 19.50 b                                  | 29.25 a                   | 21.00 b                     | 18.25 b                     |
| 1                                     | 28.00 a                    | 28.00 a       | 19.50 b                                  | 18.00 b                                  | 28.00 a                   | 20.00 b                     | 17.50 c                     |
| 3                                     | 31.00 a                    | 29.00 a       | 20.00 b                                  | 17.25 b                                  | 30.00 a                   | 20.00 b                     | 17.25 c                     |
| 6                                     | 28.50 ab                   | 30.00 a       | 21.75 cb                                 | 19.25 c                                  | 29.00 a                   | 22.50 b                     | 18.50 b                     |
| <b>External appearance</b>            |                            |               |  |  |                           |                             |                             |
| 0                                     | 32.00 a                    | 31.50 a       | 24.25 b                                  | 22.25 b                                  | 31.75 a                   | 25.25 b                     | 21.25 c                     |
| 1                                     | 31.00 a                    | 30.50 a       | 22.75 b                                  | 19.50 b                                  | 30.75 a                   | 23.00 b                     | 19.25 c                     |
| 3                                     | 32.00 a                    | 30.50 a       | 24.00 b                                  | 19.25 c                                  | 31.25 a                   | 23.25 b                     | 20.00 b                     |
| 6                                     | 32.50 a                    | 32.00 a       | 23.25 b                                  | 19.75 c                                  | 32.25 a                   | 24.25 b                     | 18.75 c                     |
| <b>General acceptability</b>          |                            |               |  |  |                           |                             |                             |
| 0                                     | 31.00 a                    | 30.50 a       | 21.00 b                                  | 20.00 b                                  | 30.75 a                   | 22.25 b                     | 18.75 c                     |
| 1                                     | 28.00 a                    | 28.00 a       | 19.50 b                                  | 17.50 b                                  | 28.00 a                   | 20.25 b                     | 16.75 c                     |
| 3                                     | 32.00 a                    | 30.00 a       | 20.25 b                                  | 17.00 b                                  | 31.00 a                   | 20.00 b                     | 17.25 b                     |
| 6                                     | 31.00 a                    | 31.00 a       | 22.00 b                                  | 18.25 b                                  | 31.00 a                   | 22.25 b                     | 18.00 c                     |

<sup>a</sup> Means having the same letter for the same storage time are not significantly different ( $\alpha = 0.05$ ).

<sup>b</sup> NF = Navy bean flour, NC = navy bean protein concentrate.

<sup>c</sup> PF = Pinto bean flour, PC = pinto bean protein concentrate.

<sup>d</sup> Total sum of five panelist sessions.

**TABLE III**  
Duncan's Multiple Range Test for Acidity, Moisture, and Color Score of Spaghetti Made of Semolina-Legume Blends After Different Storage Times

| Variable/<br>Storage Time<br>(months) | Legume Effect <sup>a</sup> |               |  |  | Flour Effect <sup>a</sup> |                             |                             |
|---------------------------------------|----------------------------|---------------|--|--|---------------------------|-----------------------------|-----------------------------|
|                                       | Control No. 1              | Control No. 2 | Spaghetti<br>with NF and NC <sup>b</sup> | Spaghetti<br>with PF and PC <sup>c</sup> | Controls<br>Nos. 1 and 2  | Spaghetti<br>with NF and PF | Spaghetti<br>with NC and PC |
| <b>Acidity (ml 0.1 M NaOH)</b>        |                            |               |  |  |                           |                             |                             |
| 0                                     | 1.50 b                     | 1.75 ab       | 1.95 a                                   | 1.95 a                                   | 1.63 b                    | 1.60 b                      | 2.30 a                      |
| 1                                     | 2.03 b                     | 2.08 b        | 2.94 a                                   | 2.98 a                                   | 2.05 c                    | 2.85 b                      | 3.06 a                      |
| 3                                     | 1.90 c                     | 2.15 b        | 3.18 a                                   | 3.10 a                                   | 2.03 c                    | 2.80 b                      | 3.48 a                      |
| 6                                     | 2.75 b                     | 3.20 a        | 3.11 ab                                  | 3.28 a                                   | 3.08 b                    | 2.95 b                      | 3.44 a                      |
| <b>Moisture (%)</b>                   |                            |               |  |  |                           |                             |                             |
| 0                                     | 9.80 ab                    | 9.90 a        | 9.83 ab                                  | 9.73 b                                   | 9.85 a                    | 9.83 a                      | 9.73 a                      |
| 1                                     | 9.15 a                     | 9.05 ab       | 8.95 b                                   | 8.98 ab                                  | 9.10 a                    | 9.05 a                      | 8.76 b                      |
| 3                                     | 8.40 a                     | 8.10 ab       | 7.90 b                                   | 7.93 b                                   | 8.25 a                    | 7.95 ab                     | 7.88 b                      |
| 6                                     | 8.00 a                     | 7.80 ab       | 7.75 ab                                  | 7.63 b                                   | 7.90 a                    | 7.53 b                      | 7.85 a                      |
| <b>Color score</b>                    |                            |               |  |  |                           |                             |                             |
| 0                                     | 8.50 a                     | 8.50 a        | 7.00 b                                   | 7.13 b                                   | 8.50 a                    | 7.13 b                      | 7.00 b                      |
| 1                                     | 9.00 a                     | 8.00 b        | 7.00 d                                   | 7.25 c                                   | 8.50 a                    | 7.25 b                      | 7.00 c                      |
| 3                                     | 8.25 a                     | 8.00 a        | 7.25 b                                   | 7.25 b                                   | 8.13 a                    | 7.50 b                      | 7.00 c                      |
| 6                                     | 9.00 a                     | 9.00 a        | 7.63 b                                   | 7.25 c                                   | 9.00 a                    | 7.88 b                      | 7.00 c                      |

<sup>a</sup> Means having the same letter are not significantly different ( $\alpha = 0.05$ ).

<sup>b</sup> NF = Navy bean flour, NC = navy bean protein concentrate.

<sup>c</sup> PF = Pinto bean flour, PC = pinto bean protein concentrate.

legume protein concentrates showed good color score (a good score is 8.5 or above). Only controls reached this score, followed by spaghetti containing legume flours (7.13-7.80) and legume concentrates (7.00).

### CONCLUSION

Spaghetti fortified with 10% (w/w) legume concentrates (with protein content of 22.5% for navy and 22.2% for pinto on a 13% moisture basis) met FDA specifications for protein content. Although panelists showed a preference for traditional products (controls) for the storage times tested, spaghetti fortified with navy flour or concentrate obtained acceptable scores. Flour effect and other analyses indicated that spaghetti fortified with legume flours was acceptable in terms of shelf life stability. The results suggest that further studies should focus on developing the most preferable amount of a combination of navy flours and concentrates to fortify spaghetti.

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