

CRICKET FLOUR-LADEN MILLET FLOUR BLENDS' PHYSICAL AND CHEMICAL COMPOSITION AND ADAPTATION IN DRIED PASTA PRODUCTS

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Increasing the protein and antioxidant content of food products is a constant challenge amongst researchers. Dried pasta products are popular amongst all groups of society. The most important factor in pasta processing is the quality of the flour. Millet (*Panicum miliaceum*) flour has high nutritional value, enriching it with cricket (*Gryllus bimaculatus*) flour is good choice to increase the quality of protein composition and antioxidant properties of products. Flour mixtures of millet and insect flours (5% and 10%) were analysed after mixing and pasta processing. Addition of wheat gluten improved both texture and nutrition value of pasta products. Total polyphenol content, antioxidant capacity, total protein content, free and total amino acid composition were studied. Quality analysis of dried pasta products were carried out according to Hungarian standards. Data was analysed with Kruskal-Wallis test, Dunn's pair-wise post hoc test was used with Bonferroni correction. The correlation was determined by Spearman's rank. Addition of cricket flour modified the pH, acid value, moisture content, and colour of the samples, these changes lasted during storage. Enrichment could increase the total phenol content significantly even at the low level of 10%. Heat treatment during pasta processing had negative effect on the antioxidant capacity except at higher cricket flour contents. Cricket flour's high protein content proportionately increased millet flour's, thus pasta products'. Dried pasta products passed all quality norms. Enrichment of millet flour with cricket flour is favourable from both nutritional and quality aspects.

Keywords: insect flour, millet flour, antioxidant capacity, amino acid composition, dried pasta quality

Nutrition is a key factor in food research. The pursuit for new ways to integrate different macro- and micronutrients in the diet of consumers is constant. However, it seems that the majority of human population still consume food one-sidedly. Both social, cultural, and economic factors contribute to the development and change of dietary patterns. Availability and knowledge are key factors in the spread of a food product (ROZIN & ZELLNER, 1985).

The rising income level and population growth results an increasing demand for food, especially for protein. The consumption of protein rich food products is necessary to maintain human metabolism. However, the need is not only confined to the quantity of protein in human diet, the quality is also crucial. Choosing higher quality protein sources could fill the void in essential amino acid consumption, thus preventing malnutrition of an individual (PAYNE, 1978).

In Hungary, dried pasta products are popular amongst all groups of society. Its position is also safe in the global market as well. The amount of dried pasta products consumed in recent years is elevating. This trend results that the food industry continuously tries to lower

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production costs, improve profit and nutritional value of products (KUMAR & PRABHASANKAR, 2014).

The most important factor in pasta processing is the quality of the flour used. Choosing good quality base flour can radically improve the nutritional value of the product.

Millet (*Panicum miliaceum*) flour is a good replacement or addition for wheat flour. All types of millets were found to have high nutritive value, comparable to the major cereals such as wheat and rice (PARAMESWARAN & SADASIVAM, 1994). TIWARI and SRIVASTAVA (2017) had shown that foxtail millet flour exhibits higher functional characteristics than refined wheat flour. Furthermore, proso millet varieties have high content of slowly digestible starches, thus are good sources of dietary fibres, which can help digestion (TYL et al., 2017). It has also been reported that millet proteins are good sources of essential amino acids except lysine and threonine, but are relatively high in methionine. Millets are also rich sources of phytochemicals and micronutrients (MAL et al., 2010; SINGH & RAGHUVANSHI, 2012).

The best way for improving the millet flour's amino acid composition is enrichment. In case of the millet flours – as mentioned above – there is a hiatus of the amino acids: lysine and threonine. To supplement these amino acids, one way is addition of an alternative protein source. To address the hiatus of lysine content of millet flour and to improve the texture of the pasta products, the best way is the addition of wheat flour.

The use of insect flours is more and more accepted in the western culture, and the shift from animal protein is necessary not just for the health of our planet but for ours as well (GODFRAY, 2010; THORNTON et al., 2011; WU, 2014; MÉZES, 2018). The production of insect flour is fast, cost effective, and environmentally friendly. The preparation is highly supervised and controlled by the Food and Drug Administration (FDA, 1998), as well as the European Union (EC, 1997). Cricket (*Gryllus bimaculatus*) flour is a good choice to add to millet flour. With its high protein and low carbohydrate content it can positively alter the nutritional value of the product without having a large environmental footprint.

Addition of insect flour could change the sensory properties of a given food product. Millet flour has a relatively neutral flavour and smell. Depending on quantity, rationing of cricket flour could result aftertaste and unappetizing smell of food products. Studies suggest that consumer acceptance of edible insect-laden products can be enhanced by processing and blending with familiar food products (PAMBO et al., 2018). Using a prevalent product, like dried pasta, is a great start in introducing insect flours into western diet.

The aim of this study was to analyse the chemical behaviour of millet flour enriched with cricket flour in different quantities. Also the chemical and quality properties of the dried pasta products made from these flour mixtures were investigated. Another goal was to evaluate the possibilities of cricket flour-laden pasta in industrial processing and on commercial market.

1. Materials and methods

1.1. Materials

The flours were bought commercially. The bio millet flour (*Panicum miliaceum*) and wheat gluten were produced by GreenMark Organik, the *Gryllus bimaculatus* cricket flour was purchased from ThailandUnique. The reagents for the chemical measurements were provided by Reanal llc.

1.2. Samples

All measurements were carried out on the pure flours as well as the flour mixtures. For the enriched flours, the millet flour and the cricket flour in two different compositions (5% and 10% of cricket flour by weight of the whole mix) were mixed.

The pastas were made from both the pure millet flour and the flour mixtures. To give structure and further improve protein composition of the pastas, wheat gluten (20% of the weight of dry matter) was added. After mixing the dry matter, the pastas were formed with the addition of water (50% of the weight of dry matter). The quantities of these additional ingredients were kept the same in every recipe.

After the right amounts of both flours were weighing, wheat gluten was added. After homogenizing the powder mixture in a mortar, it was stirred in the water. The pastas were kneaded by hand, rolled and cut by Mercato Atlas Deluxe 150 type pasta machine into strips. The drying process was executed in an Armfield type fluid dryer for 20 minutes at 80 °C. From pure cricket flour no pasta could be made with these test conditions.

The samples were subjected to chemical measurements. In preparation, 100 mg ml⁻¹ extracts were made with distilled water. The pasta products were grated in a mortar, the extracts were made from the powder. Every analytical method was carried out on three parallel samples.

1.3. Methods

1.3.1. Chemical analysis. Both the flour mixtures and the dried pasta products were evaluated with chemical methods.

Moisture content was determined with Sartorius MA 50 type fast moisture analyser. Water activity was measured with Novasina Lab Master. For the colour measurement the Minolta Chromameter CR-310 device with tristimulus objective in Lab coordinate system was used on powdered samples. For pH measurement, a Mettler Toledo SevenGo Duo pH/conductivity meter SG23 hand device was used. The determination of pH and acid value was carried out based on Hungarian standards (1985a).

Total water-soluble polyphenol content was measured by Folin-Ciocalteu method (SINGLETON & ROSSI, 1965) and expressed in gallic acid equivalent (GA). Water soluble antioxidant capacity was measured using FRAP (ferric reducing antioxidant power) assay (BENZIE & STRAIN, 1996) and given in ascorbic acid equivalent (AA). For measuring the water-soluble protein content, Layne method was used (LAYNE, 1957). For the spectral analysis, Rayleigh UV1800 type spectrophotometer was applied. Total and free amino acid contents of the samples were measured with an Iqnos AAA 400 Automatic Amino acid Analyser, sample preparation went according to the manufacturer's instructions. The amino acid profiles were determined with Chromulan V 0.82 software and given in µg g⁻¹ unit.

1.3.2. Quality analysis of dried pasta products. To determine the adaptation of the pastas in commercial trade, Hungarian Standards (1985b) were used. Measurement of optimum cooking time, swelling capability, disintegrating and sticking during cooking, and sensory evaluation were carried out.

1.3.3. Statistical evaluation. All measurements were carried out in five replicates, using XL-stat software. Because of the parallel samples, non-parametric probes were used. The Kruskal-Wallis test was applied to calculate the p-value ($\alpha=0.05$), and Dunn's pair-wise post

hoc test was used with Bonferroni correction on significant results. The correlation between parameters was determined by Spearman's rank correlation (non-parametric equivalent of Pearson's correlation) ($\alpha=0.05$).

2. Results and discussion

2.1. Physical and chemical properties

2.1.1. Moisture content and water activity. The moisture content and water activity of all samples were below the limit given by Hungarian Standards. Addition of the cricket flour lowered both values in flour mixtures and pastas as well. In the case of mixtures, addition of cricket flour at 5% and 10% lowered moisture content by 2.58% and 5.79%, respectively.

Water activity of the mixtures increased at 5% supplementation by 1.88% and at 10% supplementation by 4.93%. These values are relatively high given the added content. In the case of both types of enriched pastas, the increase was 10%.

2.1.2. pH and acid value. The cricket flour's pH was higher than the millet flour's (6.21 ± 0.10 and 6.01 ± 0.02 , respectively). The pH of the mixtures followed the same trend as the moisture content and the water activity. The dried pasta's pH was lower than the relating flour's (pure millet: 5.97 ± 0.07 ; 5%: 6.00 ± 0.01 ; 10%: 6.01 ± 0.01).

The cricket flour had relatively high acid value at the start (23.78 ± 0.042), which enhanced the value of the mixtures (from 5.02 ± 0.021 ; 5% mix: 7.24 ± 0.04 ; 10% mix: 15.78 ± 0.01). The acid value of pasta products was lower than the base flour's. The millet flour pasta had 4.59 ± 0.04 , the 5% pasta: 2.02 ± 0.02 and the 10%: 4.95 ± 0.04 acid value. This means that the method of pasta processing protects from lipid oxidation that could occur in the flour samples.

2.1.3. Colour measurement. The addition of cricket flour changed the colour of flour mixtures and dried pastas visibly. For evaluating the obtained colour data, statistical analysis on flours and pastas was used together.

The lightness (L^*) value decreased with increasing the added amount of cricket flour, because the cricket flour has darker colour ($L^*=43.11\pm 0.21$) than millet flour ($L^*=90.16\pm 0.13$). The a^* value gives the greenred axis, the b^* the blueyellow axis of the colour chart. The increasing ratio of cricket flour resulted redness (rising value of a^* value) and blueness (lowering in b^* value) in the mixtures.

2.2. Antioxidant properties

2.2.1. Water-soluble total polyphenol content. The water-soluble (WS) total polyphenol content of the flours and pastas are given in mg gallic acid/g dry matter (Fig. 1). The lower amount in the 10% flour mixture can be caused by inhomogeneity of the sample. The pairwise comparison gave two homogeneous groups and at least two samples were significantly different amongst all samples. The least amounts of polyphenolic compounds were measured in 100% millet flour and 100% millet flour-based pasta. The highest amount group contained the 100% cricket flour and the 10% cricket flour-based pasta. According to the data, the addition of cricket flour could increase the phenol content significantly even at the low level of 10%. This means a two-fold elevation from 0.125 ± 0.008 mg GA/g DS (100% millet flour-based pasta) to 0.252 ± 0.043 mg GA/g DS (10% cricket flour-based pasta).

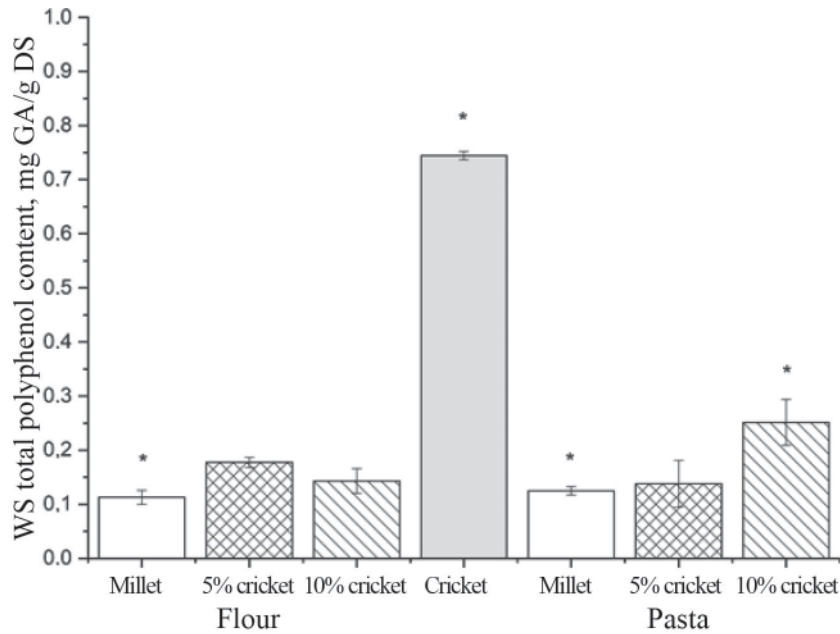


Fig. 1. Water-soluble total polyphenol content of the flour and pasta samples given in mg gallic acid/ g dry matter. White, squared, striped, and grey columns represent 100% millet flour and pasta, 5% cricket flour mixture and pasta, 10% cricket flour mixture and pasta, and 100% cricket flour, respectively. Stars above the columns mark significantly different values ($P < 0.05$).

2.2.2. *Water-soluble total antioxidant capacity.* WS antioxidant capacity can be seen in Figure 2. The Dunn-type post hoc test determined three groups amongst the samples. Two of those were homogeneous groups. The lowest antioxidant capacity was for 100% millet flour and 100% millet flour-based pasta, the highest value belonged to the 10% cricket flour-based pasta. The pairwise comparison found that there was significant difference between the dried pasta samples made with 5% and 10% cricket flour.

According to these results, we are able to say that addition of cricket flour to the base mixture significantly increases the antioxidant capacity both of flour mixtures and pasta products. Also, it can be stated that heat treatment has negative effect on the antioxidant capacity except in case of higher cricket flour content, where the value significantly rose after pasta processing.

2.3. Protein content

2.3.1. *Water-soluble total protein content.* From the measured values of WS protein, the statistical analysis defined three groups, two of those were homogeneous. There were at least two significantly different samples as well. The lowest content was measured in the 100% millet flour ($32.98 \pm 2.52 \text{ mg g}^{-1}$) and the highest in the 100% cricket flour ($138.11 \pm 5.41 \text{ mg g}^{-1}$) and the 10% cricket flour-based pasta ($84.32 \pm 4.46 \text{ mg g}^{-1}$). The addition of cricket flour elevated the protein content of the mixtures. However, this trend was not clear in the pasta samples.

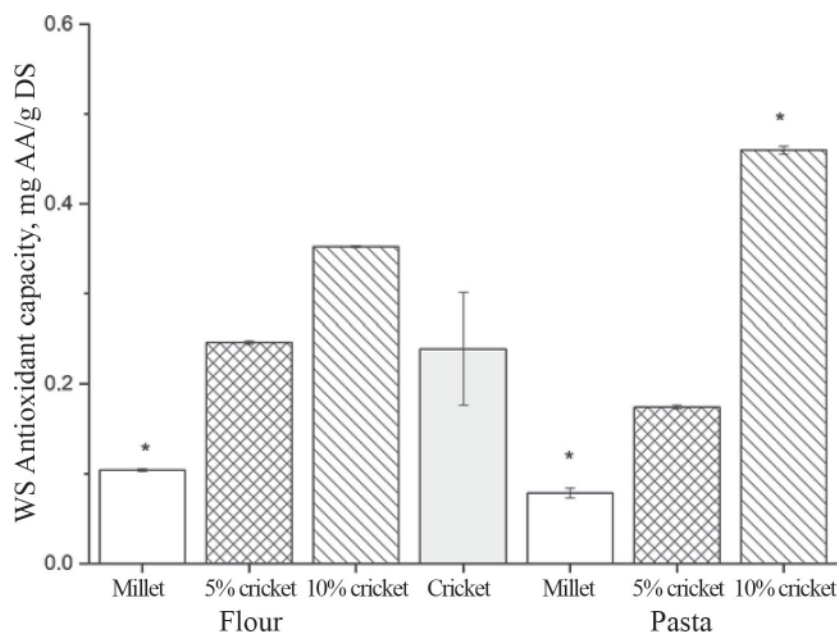


Fig. 2. Water-soluble total antioxidant capacity of the flour and pasta samples given in mg ascorbic acid/g dry matter. White, squared, striped, and grey columns represent 100% millet flour and pasta, 5% cricket flour mixture and pasta, 10% cricket flour mixture and pasta, and 100% cricket flour, respectively. Stars above the columns mark significantly different values ($P < 0.05$).

There was significant difference between the protein content of the millet flour and the cricket flour and between the 10% cricket flour-based pasta and the 5% cricket flour-based pasta.

In the case of 100% millet flour and 10% cricket flour mixture, the processing of pasta products resulted in significant elevation of protein content. In the pasta samples made from the 5% cricket flour mixture the protein content has not changed significantly, this low amount of added cricket flour was not enough to relevantly change the nutritional value of the final product.

2.3.2. Total and free amino acid content. The reason of measuring both the total and free amino acid compositions was the fact that insect flours contain essential amino acids for humans, thus they not only increase the quantity of protein content but the quality of protein composition as well (CHURCHWARD-VENNE et al., 2017).

The evaluation of free amino acid composition was carried out by Chromulan V 0.82 software provided by the manufacturer, and the values were given in mg g^{-1} unit. The total amino acid composition was given in $\text{g}/100 \text{ g}$ unit.

The lowest amounts of total amino acid content were in the 100% millet flour and 100% millet flour-based pasta. The cricket flour had twice as much total amino acid value than the millet flour ($59.2 \pm 0.7 \text{ g}/100 \text{ g}$ and $25.6 \pm 1.6 \text{ g}/100 \text{ g}$, respectively) and this deviation was significantly different. The addition of cricket flour increased the protein content proportionately.

As mentioned above, millet flour is deficient in the amino acids threonine and lysine. The contents of these amino acids were relatively low in the 100% millet flour, 3.116 mg g⁻¹ and 1.802 mg g⁻¹, respectively. In contrast, the amounts of these amino acids were high in the 100% cricket flour (21.1 mg g⁻¹ and 13.6 mg g⁻¹, respectively). The difference caused a favourable increase of the amounts of these amino acids in the mixtures and the flour mixture-based pastas. The total amino acid content was always lower in the flour mixtures, which means that pasta processing could improve protein composition.

2.4. Quality of dried pasta products

The quality properties were analysed according to Hungarian Standards. Cooking times of all three types of pastas were between 3.5–4 minutes. The highest swelling value belonged to the 10% cricket flour based dried pasta, which means that the addition of cricket flour improved the swelling capability of the millet flour. The disintegrating and sticking values of pasta were below the allowed limit.

Sensory analysis of alternative pasta products measures taste, smell, outer appearance, consistency, and cooking properties. According to these values, there are three quality classes for pasta products. The 100% millet flour-based pasta fell into the I. class of quality groups. The cricket flour content lowered the sensory properties of pastas resulting in quality descent to II. class.

2.5. Statistical evaluation

On the significant differences between our data, Pearson's type correlation studies were carried out. The correlation between four factors: WS total polyphenol content, WS total antioxidant capacity, total amino acid content, and WS total protein content were examined.

Based on the obtained "r" and "p" values (Tables 1 and 2) we found that all parameters correlate positively in some degree. Strongly positive correlation was found between WS total polyphenol content and WS total antioxidant capacity. This relationship was determined by KIM and co-workers (2010) as well, while studying antioxidant properties of different types of millets.

Two other moderately strong correlations were determined between the groups. One was found between WS total polyphenol content and total amino acid content. The cause of this correlation could lay in polyphenolicprotein interactions in the matrix of samples. For evaluating molecular changes happening in the food matrix, further measurements are necessary. The second was found between WS total antioxidant capacity and amino acid content. The concept that proteins can act as antioxidants are discussed in recent years based on their molecular structures, hydrolysates, and amino acid sequences (ALUKO, 2015)

Table 1. "r" values of the Spearman correlation matrix of the four studied parameters (r = 0 no linear correlation, r = -1 perfect negative correlation, r = 1 perfect positive correlation)

Variables	WS total polyphenol content	WS total antioxidant capacity	Total amino acid content	WS protein content
WS total polyphenol content	1	0.6973	0.6567	0.4387
WS total antioxidant capacity	–	1	0.9563	0.3600
Total amino acid content	–	–	1	0.3507
WS protein content	–	–	–	1

Table 2. “p” values of the Spearman coefficient determination matrix of the four studied parameters

Variables	WS total polyphenol content	WS total antioxidant capacity	Total amino acid content	WS protein content
WS total polyphenol content	0	0.0000	0.0000	0.0014
WS total antioxidant capacity	–	0	<0.0001	0.0047
Total amino acid content	–	–	0	0.0054
WS protein content	–	–	–	0

3. Conclusions

Addition of cricket flour could improve physical, chemical, and storage properties of millet flour-based flour mixtures and dried pasta products. All measured parameters passed Hungarian Standards. Antioxidant capacity, total polyphenol content, and protein content improved with enrichment. Cricket flour compensated for the hiatus in millet flour’s amino acid composition, increasing the amounts of threonine and lysine. The processing method of pasta products improved antioxidant capacity and protein content. Enrichment of millet flour with cricket flour is favourable from both nutritional and quality aspects. Although millet flour is a popular gluten free option, the focus was rather on the nutritional improvement than the gluten free status of our products. In the future, development of insect flour enriched pasta products as well as designing gluten free options could be one of the prospects of the food industry.

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