

Summary

Bee products such as honey, pollen, beebread or propolis are a valuable source of nutrients and biologically active ingredients. They show a beneficial effect on the human body, which manifests itself by general improvement of well-being as well as a faster recovery from diseases. However, due to the limited sensory appeal of such bee products as pollen, beebread or propolis, including them in the diet is not a simple matter. For this reason, the most natural way to introduce these valuable ingredients into the diet is to add them to honey.

The aim of this work was to broaden the knowledge of the impact of honey enrichment with pollen, beebread or propolis on the increase of bioactive compounds content, including phenolic acids and flavonoids, antioxidant potential and sensory, physicochemical and qualitative characteristics.

The total content of polyphenols, flavonoids, phenolic acids, anthocyanins, carotenoids and vitamin C was determined by spectrophotometric methods. The polyphenolic profile including the content of selected flavonoids and phenolic acids was determined using high performance liquid chromatography (HPLC-DAD). In the assessment of antioxidant activity, reactions with the molybdenum reagent and the radicals DPPH[•] and ABTS^{•+} were used. The reduction capacity was also determined by the FRAP and CUPRAC methods. The sensory analysis was performed by a team of 14 people, tested in terms of sensory sensitivity and trained. In the research the method of quantitative descriptive analysis was used and acceptance was assessed using the hedonic scale. Instrumental colour measurement was performed by spectrophotometric reflection method. The parameters characterising the commercial quality of honey were determined in accordance with the requirements of the Regulation of the Ministry of Agriculture and Rural Development (2009). The mineral composition was also determined using atomic absorption spectrometry with flame atomisation (F-ASA) after dry sample mineralisation.

Based on the obtained results, the addition of bee products to honey had a clear impact, not only quantitative but also qualitative, on the occurrence of specific groups of bioactive compounds. Pollen and beebread in proportion to the total polyphenol content provide flavonoids, phenolic acids and anthocyanins. However, propolis, although added to honey in much smaller quantities, provides the most phenolic acids, the content of which increases the most when its concentration increases. The addition

of bee products to honey also resulted in a significant increase in the content of carotenoids. The pollen added to honey contributed to the increase in the content of marked flavonoids, among which the highest proportion had kaempferol (2,183 mg/100 g with the maximum concentration of pollen). The addition of beebread to honey increased the content of all flavonoids tested, with the highest increase observed in the case of quercetin, the content of which was determined at 0.868 mg / 100 g with its 25% addition. However, the increasing addition of propolis multiplied the content of all marked flavonoids in honey. In the samples enriched with propolis, chrysin was found in the highest concentration (10,851 mg/100 g). Pinobaxin and pinocembrine were also found in honey enriched with propolis.

Enrichment of honey with pollen caused an increase in the content of marked phenolic acids, the highest of which was gallic acid (1,494 mg/100 g). The growing addition of beebreads multiplied the content of all phenolic acids in honey, among which the highest amount of gallic acid (1,104 mg/100 g). The addition of propolis to honey increased the content of all marked phenolic acids, with the highest increase observed in the case of p-coumaric acid, the content of which was 24.44 mg/100 g with the maximum addition of 1% propolis.

The result of the increasing content of polyphenolic compounds was the observed increase in antioxidant, antiradical and reducing activity, taking into account the type of ingredient added. A positive, statistically significant linear correlation was observed between the total content of polyphenolic compounds and the total content of flavonoids ($r = 0.9097$) and the total content of phenolic acids ($r = 0,6136$).

The enrichment of honey with bee products, which were varied in terms of quantity and quality, contributed to the deterioration of sensory properties. There was a change in colour, palatability, texture and smell. There was a significant increase in the turbidity of the samples along with the increasing addition of bee products, and the addition of beebread contributed the most to the reception of this feature. There was also an increase in feelings of sharpness and acidity as well as a decrease in the impression of sweetness. The biggest noticeable difference in the perception of impressions related to the change in texture of honey was the increase in the sensation of sandiness and the loss of the smoothness and deliquesce in the mouth. The addition of bee products has greatly contributed to the reduction of sweet and honey aromas in favour of a waxy smell. It was also found that the addition of propolis has the least effect on the deterioration of the acceptability of sensory characteristics, which resulted



from its lowest concentration in the final product. A definite reduction in the acceptability level for the flavour, smell, colour and texture was found for honeys with addition of pollen and beebread. The enrichment of honey with bee products also modified its colour. The increasing addition of pollen or beebread to honey has reduced the value of the L* parameter, corresponding to the brightness of the sample, while the addition of propolis increased the value of the L* parameter. The addition of pollen and beebread to honey increased the value of the parameter a* and b*, which indicates an increase in the share of yellow and red tones. The largest total colour difference occurred in the case of the addition of pollen, while the smallest degree was noticeable with the increasing addition of propolis. The addition of a variable amount of natural bee products to honey in each case increased the colour saturation and also changed the colour tone angle.

The addition of bee products to honey to a small extent resulted in a decrease in the content of sugars and HMF due to the fact that the bee products themselves contain very few of these ingredients. The analysed samples met the requirements regarding the commercial quality of honey in this respect. The content of water insoluble substances increased in honeys enriched with pollen or beebread. An increase in conductivity and a significant increase in acidity were also found. A significant increase in proline and ash content was also observed. These changes result from the fact that pollen and beebread are partially insoluble in water, contain mineral salts and significant amounts of proline. On the other hand, the increase in acidity results from the high content of organic acids, especially in the beebread. In terms of parameters such as the content of insoluble substances, the conductivity and acidity, the enriched honeys did not meet the requirements for commercial quality.

Potassium had the largest content among the marked macrelements: Ca, Mg, Na, K and micronutrients: Fe, Zn, Cu, Mn. An increase in the content of other elements in the analysed honey samples was observed with the exception of sodium, whose content did not change with the increasing addition of pollen, beebread or propolis .

The obtained results indicate that honeys enriched with bee products may be an excellent source of antioxidant compounds, so enriching honey with bee products is fully justified, however the amount of additive used is strongly dependent on changes in sensory characteristics and consumer acceptability.

