Recovery of valuable components from carrot peel as vegetable waste using microwave-assisted extraction

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To reduce food waste, the extraction technique was optimised to use the pulp remaining on carrot peel after peeling. The aim was to obtain extracts with the highest possible ***antioxidant capacity (AC), carotenoid content and polyphenol content (TPC)****, while consuming the least possible energy, i.e. without drying the raw material.*

The ground carrot peel was extracted using an ethanol-water mixture as the solvent, with the help of a microwave. The dry matter - liquid mass ratio was 1:40, by including the moisture content of the sample in the mass of the liquid. There were breaks during the microwave treatment, when the samples were rapidly cooled in ice water to ensure that the temperature did not exceed 55 °C. The temperature varying was between 38 and 50 °C during the whole treatment.

The total extraction time, including the rest period following each treatments was 38 minutes and the process was stopped by filtration.

Experiments were carried out using a central composite design (CCD). Three factors were changed:

Microwave power (100-450-800 W), treatment time (4-8-12 min), and ethanol concentration (10-35-60 V/V%).

The total phenolic content (TPC) of the centrifuged extracts was determined using the Folin-Ciocalteu method, while the antioxidant capacity (AC) was determined using the FRAP method. All analytical measurements were repeated three times.

In this study, we aimed to maximise the yield of carotenoids through colourimetric studies by optimising the extraction process without determining the precise value of the carotenoids. According to Hariadi et al. (2023), the L value decreases and the a* and b* values increase as the carrot concentration in the extract increases.This is proportional to the carotenoid concentration.*

The correlations between the three colour parameters were tested using the statistical method of correlation analysis. The resulting correlation coefficients are shown in the table. These results indicate that the correlation coefficient is higher than |0.94| in all cases, suggesting a strong correlation between the colour parameters. The correlations in the change in colour confirm the assumption of carotenoid content, so we further treated the colour intensity as proportional to carotenoid leaching.

Correlation between the color paramteres

L* : a*	-0.973
L* : b*	-0.975
a* : b*	0.942

A linear model was fitted to all the tested factors, which showed significant fit. The lack of fit was not significant, which confirms the fit.

The models equations are the following:

$$TPC\ (mg\ GAE\ L^{-1}) = 166.3 - 0.2935 \cdot t + 0.00492 \cdot P - 1.427 \cdot c$$

$$AC\ (mg\ AAE\ L^{-1}) = 133.6 + 15.16 \cdot t + 0.207 \cdot P + 0.86 \cdot c$$

$$L^* = 73.84 + 0.079 \cdot t - 0.00504 \cdot P + 0.328 \cdot c$$

$$a^* = 8.09 + 0.0.0185 \cdot t + 0.0028 \cdot P - 0.166 \cdot c$$

$$b^* = 61.83 - 0.752 \cdot t + 0.00156 \cdot P - 0.605 \cdot c$$

Where t is the time in minutes (4-12), P is the microwave power in W (100-800), c is the V/V% of ethanol (10-60).

The solvent concentration has a negative affect on the model, i.e. the yield, for several measurements (TPC, a, b*, L*). (L* is inversely proportional to the carotenoid content.) From this analysis, it can be concluded that, while ethanol is a good solvent, it can enhance the yield of some molecules, but can also degrade the structure of many bioactive components. These bioactive component are frequently sensitive and relatively unstable molecules, thus reducing the yield in the extract.*

Consequently, although the AC value increased with increasing the alcohol content, the other values decreased to a level where the optimization resulted in an alcohol content around the minimum for almost all solutions.

Optimization of the process

The method was optimised to maximize TPC, AC, a and b* values, and minimise L*. The optimal option, which maximises the yield from each component is as follows: t = 12 min; P = 800 W; c = 10%. The resulting yield would be as follow: TPC = 153 mg · L^{-1}; AC = 497 mg · L^{-1}; L* = 74.0; a* = 8,9; b* = 48.*

From an energetical point of view, a method to reduce microwave power consuption was also investigated, the resultsof which is presented as follow: t = 12 min; P = 624 W; c = 10%; yield: The TPC was found to be 152 mg · L^{-1}; the AC was 459 mg · $L^{-1}$and the L was 74.9; the a* was 8.4 and the b* was 47.7.*

It is important to note that this adjustment will result in a 7.65 % decrese in the expected results for AC and a 5,6 % decrease for a. The reduction in the other values is negligible (L* reduced by 1.22%, TPC reduced by 0.65% and b* reduced by 0.62%). This trade-off can be made in exchange for a 22% reduction in power consumed.*

In future experiments, the results of this study will be utilized to either reduce the concentration of ethanol or to investigate the use of other solvents, even by reducing the solvent ratio. This extration process has been demonstrated to be a valuable tool for obtaining substance that can potentionally be used as functional food ingrediens in the future.

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