

Investigation of soaking water produced by ultrasound-assisted chickpea soaking process

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ORIGINAL RESEARCH PAPER

Received: September 27, 2023 • Accepted: November 5, 2023

Published online: November 30, 2023

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ABSTRACT

The soaking step of dry pulse products' – e.g. chickpeas' – food processing is a time consuming process. Soaking time can be significantly reduced by ultrasonic treatment or using higher processing temperatures. The effect of ultrasonic treatment can be investigated by examining the soaking water characteristics. Ultrasound-assisted soaking of chickpeas was performed at 25, 35 and 45 °C, respectively. Additionally, control samples were also prepared without ultrasonic treatment at the same temperatures. The dynamics of the fitted curve clearly shows the relationship namely the higher the treatment temperature, the faster the hydration of the raw material for both untreated and treated groups. In contrast to control group, swelling rate of 2.00 – except the group 45 °C – is not achieved during ultrasound-assisted soaking. In case of treated group, the swelling rate was about 1.90 for all temperatures applied. The ANOVA test shows that the color of the ultrasonically treated samples was significantly different compared to the control ($F(5;12) = 207.86; P < 0.001$). Average dry matter content and °Brix value were significantly higher in the ultrasound treated group compared to the control in case of all temperatures. This may indicate the destructive effect of ultrasound, which may cause more components to dissolve out of the raw material by the end of the soaking process.

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KEYWORDS

ultrasonic treatment, pulses, swelling rate

INTRODUCTION

Chickpeas (*Cicer arietinum* L.) have been consumed since ancient times. They are rich in carbohydrates (mainly starch), protein, dietary fiber and micronutrients (Kaur and Prasad, 2021). They have high protein content, together with all the essential amino acids except sulfur-containing amino acids. The source of vitamins is also significantly higher than in most pulses. Additionally, chickpea contains in general riboflavin, niacin, thiamine, folic acid and β -carotene (Jukanti et al., 2012).

Nowadays, the prevalence of lactose intolerance, coeliac disease, as well as cardiovascular diseases and diabetes is increasing. As a result, the demand for food products free of some ingredients, such as lactose and/or gluten has significantly increased. The interest and demand for chickpeas is steadily increasing, because of their positive health benefits due to their nutritional value, which is really outstanding product feature among pulses and legumes. Chickpeas are beneficial for insulin regulation and may have a positive effect on the prevention of cardiovascular disease (Wallace et al., 2016).

Preservation technology of chickpeas, like in case of many other food products, generate by-products and raw material wastes. The reuse of these materials provides a real challenge for the food related industries. Studies have already been presented on the cooking water of various legumes and pulses. It has been observed that its physical parameters influence the quality of the finished product. The protein content of the cooking water can range from 20 to 35%, which is much lower in the soaking water (Kilicli and Toker, 2022). Tufaro and Cappa (2023) investigated the potential of chickpea cooking water usage for confectionery processing. It was confirmed that chickpea cooking water provides a good foaming properties capacity. Chickpea soaking water, also known as aquafaba, has become increasingly popular as a vegan-friendly alternative to eggs in cooking and baking in recent years. It could be used as a structuring and foaming agent as an egg white substitute (Stasiak et al., 2023). When processing dried pulses, it is important to keep the crop hydrated. This process can range from 3 to 4 or even up to 10–12 h. Adequate water uptake is particularly important during production. This depends primarily on the soaking time and the water temperature, because these factors influence the subsequent processes and the quality of the final product (Shafaei et al., 2016). However, several options are available to shorten the significantly long soaking time. Among these, the use of higher temperature water has become a common solution (Ranjbari et al., 2013). With the help of ultrasound treatment during the soaking process of the chickpeas, the properties of aquafaba can be further enhanced, as well as its techno functional features. In this process, ultrasound is used to apply high frequency sound waves to create tiny bubbles - possibly the cavitation phenomena - in the liquid. Besides varying the soaking time and temperature, ultrasonic treatment as a novel technological process can influence the properties and the composition of the soaking water, or even the technological properties of chickpea cooking water (Meurer et al., 2020). Additionally, it is also useful for cost reduction purposes. Ultrasonic treatment is commonly used as a pretreatment method due to its ability to disrupt the integrity of the cell matrix, resulting in alterations of secondary and tertiary structures, including protein aggregation and cross-linking due to oxidation (Rahman and Lamsal, 2021).



Additionally, ultrasonic treatments were applied successfully for the enhancement of the foaming capacity of egg white (Nagy et al., 2021). Another study reported a reduction in soaking time due to ultrasonic treatment. Yildirim et al. (2013) found that ultrasonic treatment not only reduces soaking time, but also cooking time during the preservation process.

MATERIALS AND METHODS

In the experiment, commercially available dried chickpeas purchased in Hungary (Happy Harvest, origin Venezia, Italy) were used. Measurements were performed in three replicates.

METHODS

Dried chickpeas were soaked in tap water with the use of ultrasound and the properties of the obtained soaking water were further analyzed.

Our aim was to double the initial moisture content of the dried chickpeas in order to produce good quality canned chickpea product. During the soaking process, samples were treated with ultrasound at different temperatures at 25, 35 and 45 °C, respectively. The weight of the chickpea samples was measured in every 30 min to detect the point, when they have doubled their original weight.

ULTRASOUND DEVICES AND ULTRASONIC TREATMENT

HBM Machines (The Netherlands) produced ultrasound bath was used for carrying out the ultrasound treatments. Treatments were performed at the level of 40 kHz and 300 W at 25 °C; 35 °C and 45 °C, respectively. Ultrasound treatments were marked later in figures and tables with 'US' abbreviation.

During sample preparation, 20 g of dry chickpea sample was weighed out into 200 ml glass containers (jars) and 200 g of tap water was poured into the vessel. Ensuring proper sound conductivity, the ultrasonic equipment was filled with tap water in which the sample vessels were placed. Having set the appropriate temperature, jars were treated in this medium. In order to maintain a constant temperature during the ultrasonic treatment, an external thermostat was connected to the system in order to ensure a constant temperature throughout the treatment.

Untreated samples were kept under the same temperature conditions as the ultrasonically treated samples (25, 35 and 45 °C).

COLOR MEASUREMENT

Color measurement of the soaking water was performed in the CIE-L* a* b* tristimulus coordinate system using a ColorLite sph850 spectrophotometer (ColorLite GmbH, Germany) in reflective mode. The main parameters of the CIE-L* a* b* colorimetric system are derived from the XYZ system. Among these, L* gives the luminosity of the colors (from 0 to 100). The higher the L*, the brighter the sample. The a* color coordinate gives the green to red coloration. The horizontal axis



of the coordinate system is -100 to 0 for the green tint and 0 to $+100$ for the red tint. Additionally, b^* is the blue and yellow coloration – blue is ranging from -100 to 0 , yellow is ranging from 0 to $+100$. With these data, the color can be described unambiguously (Fekete et al., 2014).

Final L^* , a^* and b^* values were the average of three measurement replicates per sample after hydration.

MEASUREMENT OF PH AND CONDUCTIVITY VALUES

Conductivity and pH values of the samples were measured at room temperature using a Mettler-Toledo SevenMulti™ dual pH/conductivity meter (Mettler-Toledo Kft., Hungary) calibrated at room temperature (24°C) using measuring solutions before the measurement. Three pair-wise measurements of each sample were performed at room temperature (24°C).

WATER-SOLUBLE DRY MATTER CONTENT DETERMINATION ($^\circ\text{Brix}$ VALUE)

The $^\circ\text{Brix}$ value (%) was measured with an Atago Digital Pocket Refractometer PAL-1 (Atago, Japan). In case of every group three replications were carried out according to the instructions given in the user's manual. Approximately 0.3 ml of the soaking water sample was measured per every $^\circ\text{Brix}$ value measurement.

RESULTS AND DISCUSSION

Our primary objective was to study the soaking water produced during the soaking process of ultrasonically treated chickpea samples. In order to characterize the hydration process, exponential model was fit to the calculated swelling rate values. Soaking under normal conditions requires a long time, as can be seen in Fig. 1 below. Based on our measurement carried out at 25°C , treatment time was 8 h and at 45°C less than 5 h. This could be explained as the water diffusion rates of chickpea increased with increasing soaking temperature, as it was published in the work of Yildirim et al. (2011) too. The chickpeas had reached the desired hydration level, so a shorter soaking time was sufficiently achieved.

In Fig. 1, the dynamic of the different curves clearly shows the following relationship: the higher the treating temperature, the faster the hydration of the raw material both in case of untreated and treated groups. It was observed that if ultrasonic assisted soaking process is used, the swelling ratio is lower if compared to the results of control groups at the same treatment temperature. In case of control groups of 25 and 35°C , the swelling rate achieved the value 2 , but the 45°C control group was below this value. In case of ultrasonic treated group, during long term soaking period, the swelling rate was around 1.90 taking into consideration all the applied temperatures. This is the effect of ultrasound on the structure of proteins, as it changes their spatial structure, so they can absorb less water (De Leo et al., 2017).

In order to characterize the hydration process, exponential model was fit to the calculated swelling rate values. Time constant (τ or 'tau') of the fitted model started to decrease with ultrasound treatment and higher temperature (Table 1). The higher the temperature during soaking, the lower the time constant, providing an enhanced speed of hydration process. Applying ultrasound results in even lower τ value, meaning that the hydration process becomes more rapid.



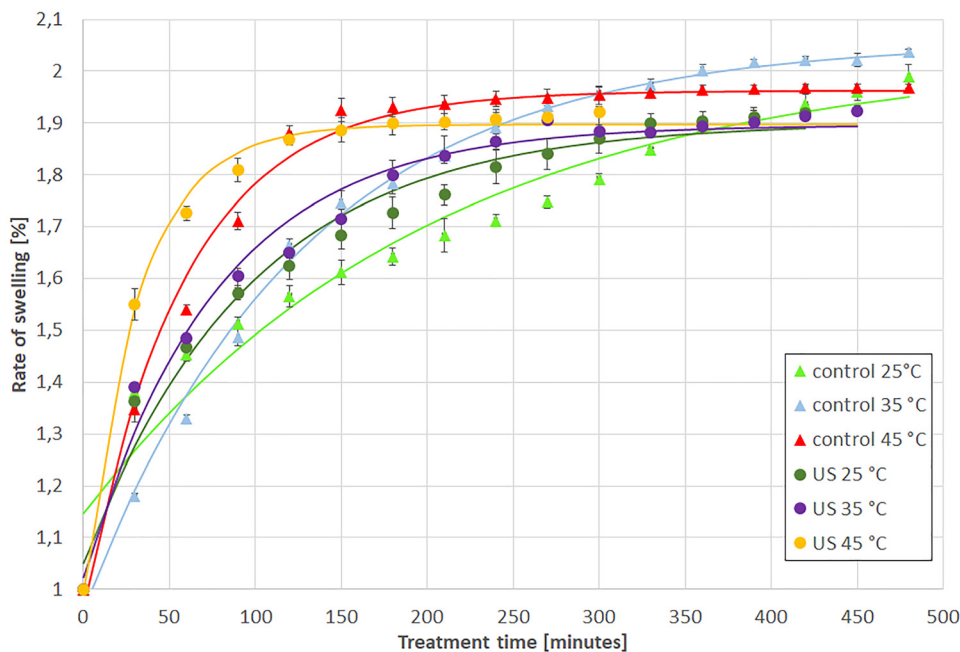


Fig. 1. Average rate of swelling in case of control and ultrasound treated samples during soaking at different treatment temperatures

Table 1. Time constants of the fitted model in case of different treatments

Temperature	τ control	τ US
25 °C	169.02 ± 10.63	101.14 ± 6.47
35 °C	118.06 ± 3.27	81.99 ± 2.53
45 °C	54.18 ± 0.72	35.32 ± 2.24

COLOR MEASUREMENT

The color of the soaking water also changed significantly at different temperatures (Tables 2 and 3). The higher the temperature during soaking, the darker the color of the soaking water. This is demonstrated by the significantly lower lightness factor (L^*) at the end of higher temperature soaking process. The ANOVA test shows that the ultrasonically treated samples'

Table 2. Average color coordinates of control samples

Control	L^*	a^*	b^*
25 °C	91.14 ± 1.13	-0.80 ± 0.06	10.41 ± 1.21
35 °C	83.36 ± 3.91	0.42 ± 0.24	12.69 ± 0.3
45 °C	57.59 ± 2.93	2.50 ± 0.19	27.50 ± 0.94



Table 3. Average color coordinates of ultrasonically treated samples

Ultrasound treated	L*	a*	b*
25 °C	51.36 ± 0.58	2.34 ± 0.1	25.82 ± 1.15
35 °C	56.87 ± 1.36	1.75 ± 0.29	28.07 ± 1.21
45 °C	44.34 ± 1.72	4.12 ± 0.39	34.92 ± 1.13

color was significantly different compared to the control ($F(5;12) = 207.86; P < 0.001$). This may also demonstrate the destructive effect of ultrasound suggesting to cause more components to dissolve out of the raw material by the end of the soaking process.

WATER-SOLUBLE DRY MATTER CONTENT MEASUREMENT (°BRIX VALUE)

Soaking process characteristic information can be gained by measuring the water-soluble dry matter content of the soaking water. Significant difference was observed among the groups (Fig. 2). Results showed that the average °Brix value was higher in the ultrasound treated group compared to the control concerning all applied temperatures. In case of control samples, the 25 and 35 °C groups had very low average water-soluble dry matter content. Only the 45 °C group showed higher (4.79%) value. There is no significant difference between 25 and 35 °C in either the control experiment or the ultrasonic treatment. However, a significant difference was observed at 45 °C. The average °Brix value of the treated samples increased with increasing temperature.

The resulting increase in °Brix value may also confirm the invasive (destructive) effect of ultrasonic treatment. This suggests that the ultrasonic treatment increases the efflux of water-soluble components of the dry matter into the soaking water.

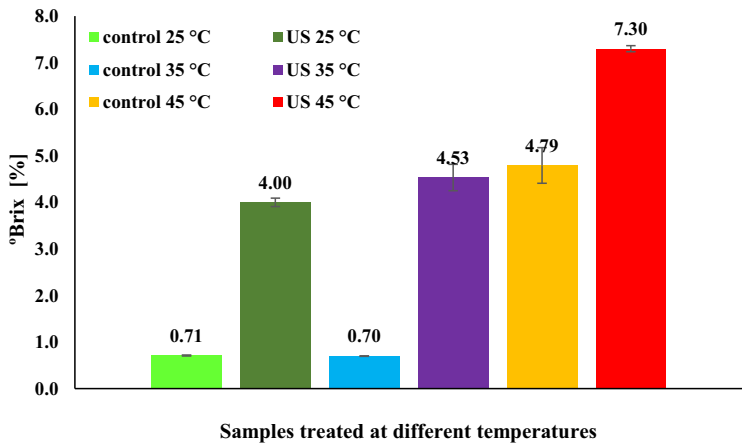


Fig. 2. Average °Brix values of ultrasound treated and control samples at different treatment temperatures



In conclusion, in addition to the positive effect of the ultrasound-assisted soaking in shortening the soaking process time, it can be observed that more components of the chickpea are transferred to the soaking water than in the case of traditionally applied soaking process (control).

The fact that valuable materials are transferred to the soaking water during the soaking process makes it necessary to investigate the further alternative usage possibilities of the soaking water. It is interesting to observe that pH values decrease (not shown) with increasing treatment temperature and ultrasonic treatment.

CONCLUSIONS

Chickpeas (*Cicer arietinum* L.) are one of the most popular pulse crops nowadays. They provide a good source of plant proteins. Further processing of dry pulses for different food products starts with the hydration of the crop, providing typically the most time-consuming step in the processing technology. It is possible to reduce long soaking times by ultrasound or by treating at a higher temperature. By using at least one of these technologies, soaking time can be effectively reduced. In the present case, we benefit from the fact that ultrasound treatment reduces soaking time, but it is important to consider that it simultaneously changes the structure of the treated sample, resulting in the removal of more components from the raw sample. The results of the measurements also confirm that there is a significant difference in water-soluble dry matter content between control and ultrasonically treated soaking water samples. The significant decrease in the lightness factor (L^*) of the samples also supports this hypothesis. The destructive effect of ultrasound on the structure results in more material dissolving into the soaking water from the crop. These results show that ultrasound treatment can reduce soaking time, which is financially advantageous, but further possibilities for the alternative usage of the soaking water should be considered.

Conflict of Interests: The last author, VZs-M, is the guest editor of the special issue this paper is part of, therefore she did not participate in the review process in any capacity and the manuscript was handled by the EiC.

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