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# The influence of immersion and contact ultrasound treatment on selected properties of the apple tissue

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ABSTRACT

Ultrasound (US) treatment is considered to be one of the most promising non-thermal technology used in the food processing. The food-related applications of this technique are linked to the analytical and technological purposes. The ultrasound waves in the food can cause the formation of micro-channels due to the systematic and alternating compression and decompression of the material (so called “sponge effect”). Additionally, in liquids the ultrasound application can cause the cavitation which can modify the food properties as well. Hence, due to its mechanism, the ultrasound treatment can also improve the extraction of pigments, aromas or antioxidants from the food matrices.

The aim of this study was to analyze the influence of ultrasound application on electrical conductivity, color, total polyphenols and antioxidant activity (determined in the ethanol extracts) of the apple tissue. The plant tissue samples were either treated by immersion method at 21 or 40 kHz or by contact ultrasound (24 kHz). The sonication lasted for 5, 10, 20, 30 min.

Ultrasound generally did not change the electrical conductivity of the analyzed material. However, the changes caused by the contact method were slightly higher. The application of ultrasound regardless the utilized method generally increased the total polyphenolic concentration up to 145.3% and the antioxidant activity by 64.5% in comparison to the intact material. Among the ultrasound treated samples, the apples sonicated by immersion method at 40 kHz were characterized by the highest total polyphenolic content regardless the sonication time. Ultrasound treatment influenced the color of the investigated material. The total color difference of sonicated samples ranged from 1.2 to 9.8, whereas the changes were most prompt in the case of contact US treatment.



## 1. Introduction

The vast majority of the unit operations and processes which are applied in the food industry is linked to the heat and/or mass transfer. For instance, the liquid food is mainly pasteurized, sterilized or UHT processed. In turn, in the case of vegetables or fruits the main preservation techniques depend on drying or freezing. Moreover, a lot of pretreatment methods depend on the heat transfer so they are called thermal techniques. For instance, in order to inhibit the enzymatic activity, reduce the microbiological load or to achieve other technological purposes food products are often blanched using hot water or steam [8]. Thermal pretreatment can also support and facilitate peeling of fruits and vegetables or impact on the textural properties of the food products [9,40,31]. The elevated temperature can enhance the kinetics of some processes and operations, for instance the osmotic dehydration [26,29]. Higher temperature is also used to enhance the extraction of some components which food contains [25,48,51]. However, the elevation of the temperature, applied in order to improve the extractability of the chemical compounds should be done very carefully due to the fact, that it can cause the decomposition of the thermolabile substances. Therefore, since few decades the interest of the food science researchers have focused on the non-thermal technologies utilization. This situation refers also to the alteration of market demands – the knowledge of consumers in the field of food processing increased hence their needs altered either. Among the non-thermal food processing methods few exhibit a very promising features and thus potentially they can be applied in an industry on a large scale. Pulsed electric field (PEF) processing could be used to preserve the food [21,50,4] or to enhance the heat/mass transfer based processes and operations [58]. Moreover, this method can also be used to enhance the extraction of bioactive compounds from the plant tissue [37,16]. Some of the research in the field of PEF processing are conducted also in the pilot or industrial scale [39,22]. Another technology

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which is considered as a non-thermal and allows both to preserve the food and to enhance some of the mass and/or heat transfer based processes is a high hydrostatic pressure (HHP) [54,2,35]. This techniques is either used to improve the extraction processes, for instance to extract flavonoids from propolis [44] or to extract the polyphenols from *Morinda citrofolia* [30].

The method which attracts enormous interests of food scientist is ultrasound. The number of scientific publications in the field of ultrasound utilization in food science in technology since 2010 exceeds 100 items and the citation number of papers dealing with ultrasounds in the field of food science equaled to almost 4000 (data obtained from the Web of Science). Moreover, ultrasound is one of the most promising techniques which allows to impact on the properties of food and to modify the kinetics of some mass and/or heat transfer based processes [41,42]. The reason of such broad possibilities of application of the ultrasound in the food science links to the effects which occur during sonication both in the liquid and solid phase of food material. The application of ultrasound can cause the cavitation of the fluid and formation of the specific bubbles which are unstable and collapse very rapidly. The collapse of such bubble causes the local alterations of the pressure and temperature which can affect the properties of the food material [32]. During the ultrasound application free radicals can be formed, which also can impact on the chemical properties of the foodstuff [38]. These two effects can be considered as a competitive regarding the impact on the antioxidant substances extraction. However, in the literature there are publications which deal with the ultrasound influence on bioactive compounds concentration in foodstuff or with ultrasound assisted extraction of such components [6,1,55]. The changes of the chemical composition due to the US treatment could result also in the alteration of other properties of the material, e.g. the color or the electrical properties. In the literature there is a lack of information regarding the influence of ultrasound on the electrical properties of the material and the analysis of this properties could deliver a useful information about the mechanism of the process and indirectly about the microstructural changes in the material.

Therefore, the aim of this study was to analyze the influence of contact and immersion ultrasound treatment on selected properties of an apple tissue. In this purpose, the electrical conductivity, color, total polyphenols content and the antioxidant activity of the fruit samples were determined.

## 2. Materials and methods

### 2.1. Material

Apples (*Malus domestica* var. *Ligol*) collected from the experimental orchard of the Faculty of Horticulture, Biotechnology and Landscape Architecture of Warsaw University of Life Sciences (WULS-SGGW) were used in the experiment. Material was stored in dark at 4 °C maximally for two days until required. Fruits were removed from the storage compartment, washed and left to equilibrate the room temperature (20 ± 1 °C). Afterwards, the material was cut parallel to the main axis of the fruit into the discs ($h$ = 5 mm; $d$ = 30 mm) without a peel.

### 2.2. Contact ultrasound treatment

After the preparation (40.4 ± 1.2 g) the samples were placed on the stainless-steel screen (Retsch, 500 μm aperture, Germany) attached to the ring sonotrode (RIS200, Hielsher Ultrasonics, Germany). The work of sonotrode was controlled by the ultrasonic processor (UIS250L, Hielsher Ultrasonics, Germany) which it was connected to. The frequency of ultrasonic waves, which were applied by the described set, was 24 kHz. Moreover, the amplitude and the duty cycle was 100%. Therefore, the ultrasonic waves propagated to the material through the screen which acted also as a sample holder. The sonication lasted for 0, 5, 10, 20 and 30 min and was controlled by a special timer (Hielsher, Germany). Ultrasound application was carried out at ambient conditions (20 ± 1 °C). Before and after each treatment the mass, dry matter content and the temperature of the apple tissue were measured. Dry matter content was determined according to the AOAC 920.15, 2002 standard. The experiment was carried out in a triplicate.

### 2.3. Immersion ultrasound treatment

Prepared samples (40.4 ± 1.2 g) were put into the baker filled with tap water (20 ± 1 °C; 12.75 ± 0.29 μS/cm) and transferred to the ultrasound bath. The ratio between the mass of the water in the baker and samples were equal to 4:1, respectively. The ultrasound application was performed by ultrasound bath (MKD-3, MKD Ultrasonics, Poland) working at 21 kHz or 40 kHz and 180 W. Sonication lasted for 0, 5, 10, 20 and 30 min and the time was controlled by the internal bath processor. Before and after each treatment mass, dry matter content and the temperature of the sample was measured. The experiment was performed in triplicate.

### 2.4. The Electrical Conductivity (EC) measurement

Electrical conductivity of the raw and sonicated apple tissue was measured using an conductometer (CPC-505, Elmetron, Poland) equipped in a self-constructed platinum dual-needle probe described previously by Wiktor et al. [57]. The measurement was performed in three replications.

### 2.5. Total phenolic content (TPC) and DPPH assay scavenging activity

In order to determine both total phenolic content of apple tissue and its scavenging activity against DPPH free radical the ethanolic extract (80% v/v) was used, accordingly to the procedure described by Sledz et al. [46]. Two independent replications of polyphenols extraction for each type of material were carried out.

Total phenolic content (TPC): The total phenolic content was determined using Folin–Ciocalteau's method [45], in accordance with modified procedure presented previously [46,34]. The absorbance was measured at 750 nm against sample without extract (Heλios Thermo Electron v. 7.03 spectrophotometer). The determination was repeated twice for each extract.

Scavenging activity against DPPH free radical: The scavenging of 2,2-diphenyl-1-picrylhydrazyl (DPPH) presented in apple's extracts was expressed as the concentration of extract required to reduce a half of free radicals (EC50). The measurement procedure was reported by Brand-Williams et al. [5] with modifications described below.

Six different concentrations of apple extracts in 80% ethanol in the range of 0.29–2.44 mg d.m./mL were prepared separately in each tube. Subsequently, the 2 mL of 100 μM DPPH solution was added to all samples. The content was stirred and the tubes were kept in the darkness for 30 min before the spectrophotometric measurement. The absorbance was read at 515 nm against 80% ethanol. The antioxidant potential of the apples tissue was determined in two independent replications and was expressed as EC50 parameter, which means a concentration of apple tissue in extract which allows to scavenge a 50% of DPPH radical (in mg d.m./mL).

### 2.6. Color measurement

The color of fresh and ultrasound treated samples was measured in the reflectance by a Chroma Meter Konica-Minolta CM-5