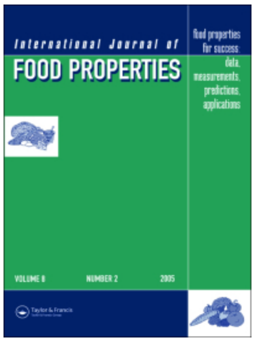

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Ultrasonic technology as a non-thermal approach for processing of fruit and vegetable juices: a review

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ABSTRACT

By inducing thermal and chemical changes, ultrasonic technology can be used to refine fruit and vegetable juices. This review focuses on the most recent successes in the use of ultrasound in the processing of fruit and vegetable juices due to the fact that ultrasonic operation and its effect on juice are distinct. Recent advancements in ultrasonic operations and their effect on the processing of fruit and vegetable juices were the subject of a comprehensive literature review. Studies have been a standard part of outcome analysis since the turn of the millennium. Key advantages of this method include the maintenance of vital components and the elimination of pulp accumulation in juices. However, this method still falls short of fully inactivating bacteria and enzymes, so gentler heat treatments are usually required.

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Introduction

In the study of ultrasound juice processing, ultrasound baths and ultrasound probes are being employed. High shear rates (i.e. the rate at which a fluid is sheared or "worked" during flow. In more technical terms, it is the rate at which fluid layers or laminae move past each other. The geometry and speed of the flow both influence shear rate), acoustic cavitation, temperature and pressure increases, and sonolysis of water molecules have all been linked to ultrasound in a liquid system. This phenomenon occurs in solid liquid systems, such as juices, despite the fact that it differs from liquid systems. Bubbles in the surrounding liquid collapse asymmetrically as a result of the particle's close contact with solid matter. Microjetting happens as a result of the rush of bubble fluid toward the surface. Upon breaking the boundary layer, particles experience rapid heat and mass transfer.[1–3]

The effectiveness of ultrasonography's application to fruit and vegetable juices depends on both external and internal factors. Environmental and equipment factors (such as temperature, processing time, ultrasound power, frequency, and amplitude) fall under the category of external factors,

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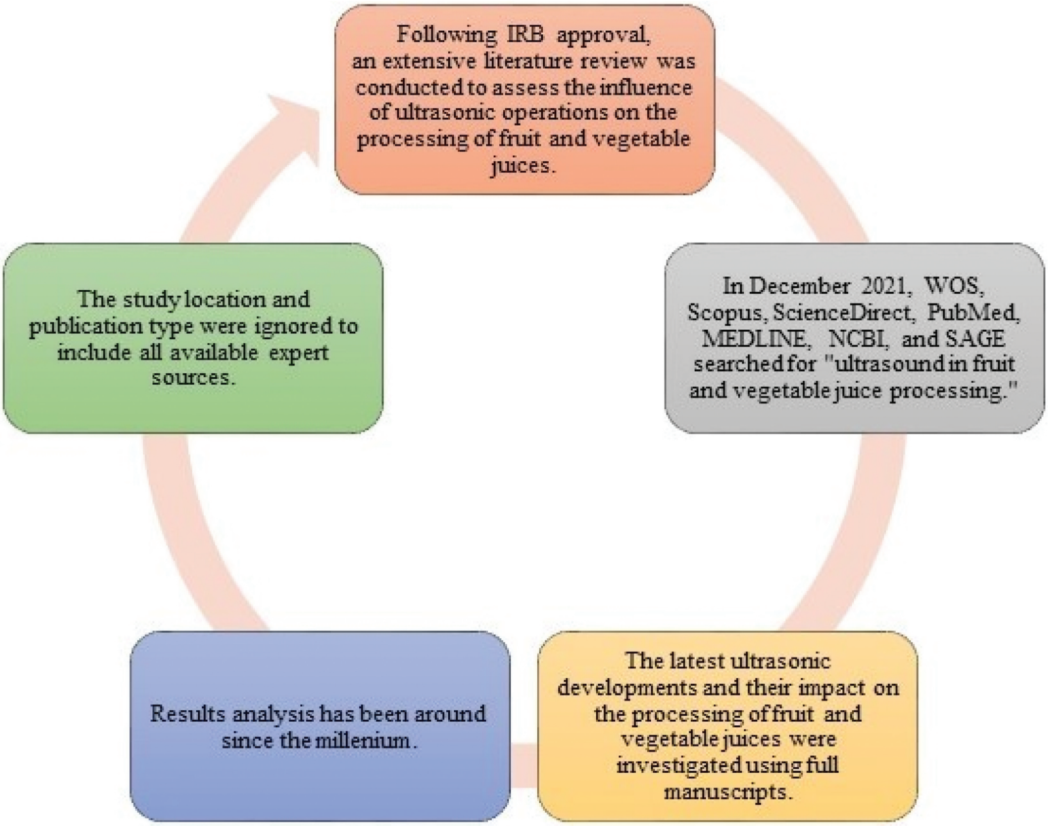

Figure 1. Method for searching the literature for information.

while the characteristics and composition of the juice matrix determine the realm of the internal factors. An external factor, like ambient circumstances or equipment, can have an impact on a juice matrix's quality and composition. Particle surface erosion, cell disintegration, and size reduction are just a few of the tiny structural alterations that ultrasound may wreak on cells and tissues. As a result of these alterations, physical, microbiological, and enzymatic stability are improved.[4–6]

Stability in physical, enzymatic, and microbiological terms is an indicator of juice quality.[7–10] As far as microbiological and enzymatic stabilities are concerned, ultrasound can help. The system's properties and stability are determined by the relative size of the system's coexisting forces.[11–14] Since ultrasonic operation and its effects on juice are distinct, this review was created to explore the most current successes in the utilization of ultrasound in the processing of fruit and vegetable juices.

Literature search

An extensive literature review was conducted after institutional review board (IRB) approval to look into the most current achievements in ultrasonic operations and their impact on the processing of fruit and vegetable juice. There was a search for "ultrasound in fruit and vegetable juice processing" in December 2021 in the Web of Science (WOS), Scopus, ScienceDirect, PubMed, MEDLINE, NCBI, and SAGE databases. This search yielded a number of abstracts that were analyzed for their usefulness. The most recent triumphs of ultrasonic operations and their impact on the processing of fruit and vegetable juices were investigated using full papers that were retrieved and reviewed. Since the turn of the millennium, studies have been a part of outcome analysis. As a means of ensuring that all possible sources of expertise were included, the study location and publication type were overlooked (Figure 1).

Influences of ultrasound on the structure and physical characteristics of juice

Ultrasound has a number of effects on the structure, physical, and technical properties of juice. Furthermore, the following section of this review is devoted to discussing these impacts in greater depth.

Ultrasound and the structure of juice

Juice structure is altered by ultrasonic processing. Polydisperse systems, like those found in fruit and vegetable juices, have an insoluble phase suspended in a viscous solution. The structure of these elements was altered by the duration of ultrasonic processing or the intensity of the acoustic energy applied to the samples.[14,15]

The alteration of the structure is not a one-to-one procedure. As a result, the cellular composition of smaller particles undergoes more profound changes. As the particle size decreases, the volume proportion of the dispersed phase increases. Furthermore, the compounds exposed by cell disruption alter the properties of the particles and serum juice, improving particle-particle and particle-serum interactions. .[4,14,16,17]

Ultrasonic processing is expected to reduce particle sizes and distribute them more uniformly. However, because particle size and distribution are determined by other processes, they are not always tied to processing time. Changes in viscosity, texture, turbidity, sedimentation, and color stability, for example, may be linked to changes in the structure of the juice during ultrasound processing.[11]

Texture and rheological properties

Structure, particle size, and composition all have an impact on the juice's rheological qualities. The flow behavior will be determined by the interaction of the coexisting forces. The amount of these forces, and hence the bulk rheology, is determined by particle size and particle volume fraction. The microscopic particles in purees or pulps are larger than 10 μm, and some of them may be flocs or colloidal particle aggregates. Brownian motion and interparticle forces are low in comparison to hydrodynamic forces for big particles.[18,19] The rheological properties of the juice may be linked to the processing conditions. Dispersion and continuous phase transitions are just two of the many complex phenomena associated with structural changes. Thus, the effect of the ultrasonic procedure on juice rheology can display nuanced behavior. The ultrasonic energy used can either increase or decrease the consistency of a food product, making it more or less fluid. .[4,11,17,20,21]Dias et al. (2015) confirmed that the "texture" parameter of ultrasound-processed soursop juice had greater sensory acceptability values than control samples.[22]

Sedimentation stability and cloud retention

Structure, particle size, and composition all have an impact on the juice's rheological qualities. Juice sedimentation can be prevented by using ultrasound processing. Stokes' rule is used to describe how large particles that are suspended in a fluid are affected by hydrodynamic forces.[11,23] Improved cloud retention is achieved through the use of ultrasound in liquids such as orange juice.[24] After centrifugation, turbidity in the supernatant is almost nonexistent in untreated samples, but it increases in treated samples.[14] Due to the larger particles (in unprocessed samples) and the smaller particles forming aggregates during centrifugation, the turbidity of the supernatant is decreased after separation (in treated samples).[14]

Color

Food's color is a significant sensory characteristic. Color can also be used to measure the nutritional and quality losses in liquid meals during manufacture and storage. Color stability is determined by storage conditions.[11] Ultrasound can help preserve the color of juices such as pineapple and peach.[14,25] Particle size, intercellular material release, and pigment stability all influence the stability of color parameters (lightness, redness, and yellowness) after ultrasound processing. This is most likely due to ultrasonography's elimination of dissolved oxygen. However, as a result of cell breakdown, degradation may happen as a consequence of more exposed pigments.[14]

Effects on microorganisms

Several experiments have been conducted to improve the microbiological stability of juices using ultrasound.[12, 24, 26] The impact of ultrasound on microorganisms will be determined by both external and internal factors, as well as the type and characteristics of the microbe.[27–29] Acid adaptability and pathogen strain influence ultrasound inactivation; thus, these aspects must be considered.[30] According to one study, a low pH reduces microbe resistance to ultrasonography, which is especially crucial in juices. Increased pulp content and juice components, on the other hand, appear to protect microorganisms. Mostly, when inoculation microorganisms are used, their resistance is lower than that of the juice's indigenous flora.[31] Despite this, using ultrasonography alone is rarely enough to produce the required effects. It has been utilized in conjunction with other technologies like as natural antimicrobials, pulsed light, heat under pressure, and, most notably, a thermal process to get superior results in the juice processing business.[13]

Effects on enzymes

Numerous studies on the use of ultrasound to inactivate enzymes such as peroxidase, polyphenol oxidase, and pectin methylesterase have been undertaken.[4,32–34] The processes of ultrasonic inactivation are enzyme-specific and dependent on the amino acid content and conformational shape of the enzyme. During sonication, the way enzymes work can be affected by a combination of chemical and physical factors happening at the same time. By changing the structure of an enzyme, these things can affect how well it works. The ways that ultrasound stops an enzyme from working are unique to the enzyme being studied and depend on its amino acid structure and conformational structure.[32,33] Fruit and vegetable juices have a high pulp concentration, which makes it harder for enzymes to be deactivated. Because of the way ultrasound interacts with particles and pulp cells, it has an effect on enzyme function. Enzyme activity increases when pulp cells are removed. The longer the ultrasonic processing time, the more polyphenol oxidase activity is created in diluted avocado puree.[4] With the aid of ultrasound and heat, juice enzyme inactivation rates can be improved.[34]

Influences on ingredients

Juices that are ultrasonically processed have a wide range of impacts on individual components or ingredients (Figure 2), as indicated below.

Compounds with bioactive properties

Carotenoids, anthocyanins, ascorbic acid, and phenolics are antioxidant-rich bioactive compounds found in fruits and vegetables. Ultrasonography's influence on these compounds has been thoroughly studied.[35–38]

However, some degradation has been seen under specific conditions due to the formation of oxidative compounds during the ultrasonic process. After ultrasound processing in juices that had

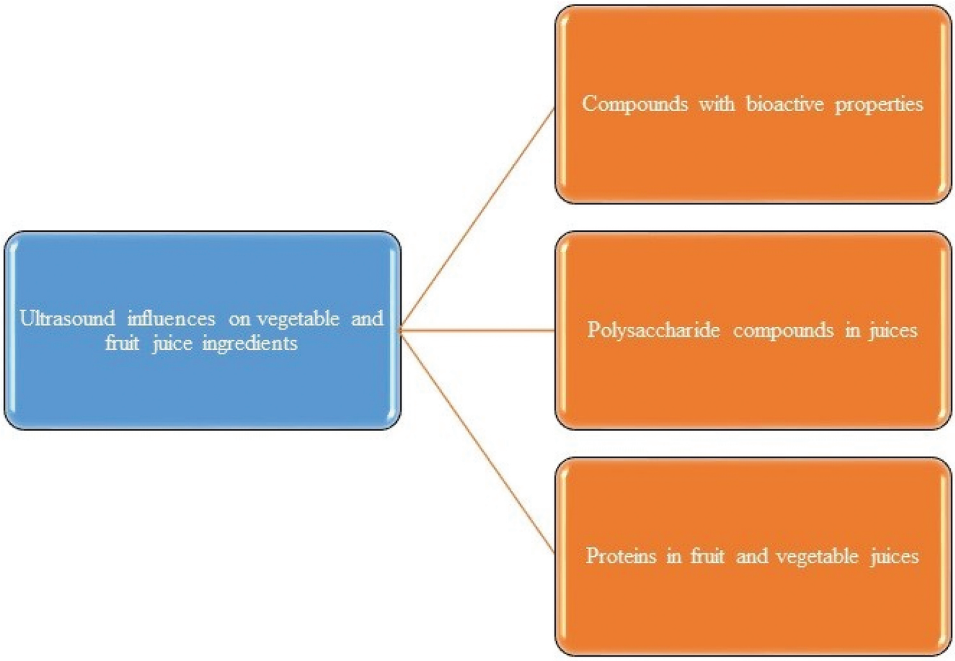

Figure 2. Influences on vegetable and fruit juice ingredients.

already been degassed, no significant ascorbic acid degradation was discovered, as stated by Aguilar et al. (2017), who endorsed this procedure to avoid deterioration.[39] Ultrasonic treatment has also been shown to reduce the amount of occluded oxygen in the juice, improving its long-term chemical stability.[40]

Polysaccharide compounds in juices

A polysaccharide molecule, pectin can be found in a wide variety of fluids. Turbidity and viscosity decreased with sonicated pectin solutions. Gelation rates of sonicated pectin solutions were also lower than those of nonsonicated samples, which may be because the shorter pectin molecule chain lengths inhibited network formation. The sugars glucose and fructose, both of which are carbohydrates, can be found in abundance in fruit juices. They are inextricably linked to the concept of sweetness. When it comes to preserving the carbohydrate profile of spinach, orange, carrot, and sweet lime juices, ultrasound processing was considerably superior to heat processing.[41]

Proteins in fruit and vegetable juices

Ultrasound has been utilized to separate protein from black beans, peas, soy, and rice. An increase in the insolubility and hydrophobicity, a rise in emulsifying activity, and an increase in protein molecular motion resulted from a lower frequency (20 kHz), medium ultrasonic power (150 W), and a short processing period (24 min). It is possible to increase the particle size of aggregates by using high-power ultrasound (450 W). Structure, carbohydrate content, and denaturation potential of rice protein isolates all contributed to the lack of detectable aggregate size reduction. In addition, primary protein structure molecular weight distribution was stable across a wide range of experimental conditions. .[42,43]

Ultrasound in juice processing: industrial and commercial considerations

On an industrial basis, ultrasound technology in juice processing is rather limited. As a result, additional research is required before this approach may be employed commercially. Furthermore, when compared to heat processing, ultrasound is seen to be a better option for retaining juice contents. Acoustic cavitation-induced equipment wear is a major challenge and constraint. As a result, notwithstanding the encouraging results thus far, selecting adequate ultrasonic equipment for juice processing on an industrial scale remains a barrier to the application of this technology.[11]

Conclusion

Ultrasound treatment has been shown to benefit fruit and vegetable juices. Among the main advantages of this method are the preservation of useful components throughout the process and the avoidance of pulp deposition in juices. This technology is still limited in its ability to inactivate microbes and enzymes, necessitating the use of other technologies, such as ultrasound, which improves the process's effectiveness and allows for the use of milder heat.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

All data are available in the manuscript.

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