Sonication of Wine – Innovative Applications of Ultrasound in Wineries

Ultrasound is a non-thermal processing method, which is already widely used in the food industry due to its mild application but significant effects on the product. For the wineries, sonication offers various applications such as the extraction of flavours, phenolics and colorants, the maturation & ageing, the oaking as well as degassing.

Wine is an alcoholic beverage, most commonly made of grapes, but also from other fruits (e.g. apple wine, elderberry wine) or starch-based materials (e.g. rice wine, maize wine).

Wine is a favored consumer good whose production requires a sumptuous process. Making quality and high quality wines is known as a time-consuming and thereby cost-intensive business. Finally, it is in winemaker's interest to speed up the fermentation (conversion to alcohol) and the maturation (to impart complex flavors and aromas) and produce at the same time a high quality liquor with the desired taste, bouquet, mouthfeel and color.

Powerful ultrasonicator UIP4000 for large volume streams

Different Effects of Ultrasonics in Wine Processing

Power ultrasound applied to wine offers many beneficial effects. The most important applications include the *flavour intensification* of the wine bouquet by extracting the flavour-rich components, such as phenolics and aromatics, the *oaking*, and the acceleration of the *maturation & ageing*.

Extraction of Aromatic and Phenolic Compounds from Grapes

Ultrasound is a well-known and proven means for the extraction of intracellular plant material and aromatic compounds. The mechanical activity of the ultrasound supports the diffusion of solvents into the tissue. As ultrasound breaks the cell wall mechanically by the cavitation shear forces, it facilitates the transfer from the cell into the solvent. The particle size reduction by the ultrasonic cavitation increases the surface area in contact between the solid and the liquid phase.

Grapes are famous and in demand for their richness in polyphenols. These phenolic compounds (such as monomeric flavanols, dimeric, trimeric, and polymeric procyanidins as well as phenolic acids) of grape are

known for their antiradical and antioxidant properties. Chemically, they can be separated in two sub-categories: the flavonoids and the non-flavonoids. The most important flavonoids in wine are the anthocyanins and tannins which contribute to color, taste and mouthfeeling. Among the non-flavonoids are stilbenes such as resveratrol and acidic compounds, such as benzoic, caffeic and cinnamic acid. Most of all these phenolic compounds are contained in the grape skin and the seeds. The intense ultrasonic forces are capable to extract the valuable ingredients from grape seeds and skin efficiently.
In the study of Cocito et al. (1995), ultrasonication has been shown as a rapid, repeatable and linear process for the extraction of aroma compounds in must and wine. The obtained results of the compound concentrations by ultrasonic extraction were higher than those of the C18 column extraction (resin extraction).
Summing up the advantages of the ultrasonic extraction, ultrasound is an inexpensive, simple and efficient alternative to conventional non-thermal extraction means, such as high hydrostatic pressure (HP), compressed carbon dioxide (cCO2) and supercritical carbon dioxide (ScCO2) and high electric field pulses (HELP). A further advantage is the fact, that ultrasonic extraction – by contrast to the alternatives named above – can be easily tested in lab or bench-top scale. These trials provide reproducible results so that a following scale-up does not require further efforts in finding the optimal setting. For full commercial production, reliable heavy-duty ultrasonicators with up to 16,000 watts per unit allow the sonication treatment of very high volume streams.

Ultrasound-Assisted Extraction for the Wine Oaking

During the stage of oaking, the wine comes in contact with the wood of the barrels (traditional oaking) or with added wood chips, wood sticks/ staves or oaking powder (alternative oaking). The most common wood for oaking (flavoring) is – according to the procedure's term – oak (quercus). Other wood types, that are used more rarely, are e.g. chestnut, pine, redwood, cherry or acacia. The chemical properties of wood are used to obtain profound effects in respect of wine's flavor and bouquet. The phenols contained in the oak interact with the wine producing flavors, such as vanilla, caramel, cream, spice or earthy flavors. A very important effect have the ellagitannins (hydrolyzable tannin), which are derived from lignin structures in wood, as they protect the wine from oxidation and reduction.
Ultrasonic extraction is useful for the stage of wine oaking due to the fact that the penetration of liquid into the wooden structure of powder, chips, sticks or staves will be enhanced by the high pressure and low pressure cycles generated by ultrasound. As thereby the mass transfer will be increased conspicuously, this entails a shorter oaking period and higher results regarding the flavor. If oak powder or wood flavor distillates (alternative oaking) are applied into the wine, the ultrasonic forces provide a very fine dispersion of the particles or droplets into the wine to improve surface wetting and exposure. This is very important to achieve a high taste and mouthfeel and contributes to the quality of the alcoholic beverage. The fact that barrelling and aging constitutes an extended time and cost factor in vinification, makes ultrasound to an exceptionally interesting processing method as Hielscher ultrasonic devices convince by low investition costs, easy implementation and an outstanding energy efficiency.

The ultrasonicator UIP500hd for ultrasonic treatment of wine

Ultrasound-Assisted Agglomeration for Wine Aging

During the traditional time-intensive aging process of wine, reactions of various molecules occur in the wine. This means that the molecules change accordingly to the interaction between each other. The time and result of this molecular change depends on the ingredients of the wine and his environment. Commonly, it is approved that alcohol is dispersed in liquors, but this does not mean that a blending of molecules will be achieved. As in wine naturally only low energy for reactions – as bonding and blending – is available, the degree of natural changes will be mostly uncompleted. While the ingredients tend to interact, attach, and change molecular properties, they cannot realize an absolute interaction, conversion, or bonding on molecular level by reason of low energy present.
As wine is sonicated (which means an input of energy into the liquid), the ingredients offer a more consistent and uniform grade of dispersion. By sonicating, wine becomes a homogeneous liquid with an extended shelf life in a very short time of treatment. The homogeneity allows a higher interaction between the molecules and thus a more complete molecular change. This means an enhancement in taste and quality.

Dispersion: Prior bottling, most wines are treated with additives, such as preservatives (e.g. potassium bisulfate, sodium bisulfate), cleansers, coloring powders and further fining agents and ameliorants. These additives are used to avoid premature browning and spoilage, to improve wine quality, to eliminate deficiencies or to support the fermenting process. By ultrasonication, these additives can be dispersed very consistently into the wine so that higher results of the processing are achieves. This leads finally to higher quality and better taste – the effort of every vintner.

Ultrasonic Extraction of Active Compounds

Wine has a broad variety of health-benefical active compounds such as tannins, phenolics, flavonoids and others, which are valuable ingredients used in the pharma, food and cosmetic industry.

Excursus

Aging of Rice Wine and Maize Wine: Chang et al. (2002) found in their study on rice wine and maize wine that the aging effects of sonication of wine depends on the kind of wine. So was the ultrasonic aging of rice wine regarding the pH value, the alcohol content, acetaldehyde, flavor and sensory qualities significantly better than the ultrasound-assisted aging of maize wine. For both, the rice wine and the maize wine, the aging time was considerably reduced (from 1 year to 1 week or 3 day).

Industrial ultrasonicators with flow-through reactors for the sonication of wine and juice.

Hielscher's Ultrasonic Processors

Hielscher is the leading supplier of high quality and high performance ultrasonic devices. Ultrasonic devices made by Hielscher are used for lab samples, pilot scale processing or full scale production in manifold reaches of industry and research. For perfect performance and adjustment to each process, Hielscher offers a wide range of ultrasonic devices for the sonication of any liquid volume, from several microliters through hundreds of cubicmeters per hour. The ultrasonic devices can be easily tested for their process efficiency at smaller scale. Typically, the UIP1000hd (1kW) is used for the process development for flow rates from 0.5L to 1000L per hour. At this scale, the processing efficiency can be optimized by varying the amplitude, pressure and flow rate. The installation or retrofitting of an ultrasound system into a production line as well as the operation and maintenance are simple and without difficulty.

Ultrasonics in Liquids

High power ultrasound generates cavitation into liquids. During the implosion of the cavitation bubbles, locally appear extremely high forces: in the cavitational "hot spot" very high temperatures (approx. 5,000K) and pressures (approx. 2,000atm) are reached. The implosion of the cavitation bubble also results in liquid jets of up to 280m/s velocity. When these intense forces go into the liquid, they cause different effects. In an alcoholic liquid, ultrasonication causes an acceleration of oxidation, polymerization, and condensation of the alcohol, aldehydes, esters, and olefins to build new compounds which create more and better flavor and bouquet.
As the most interesting ultrasonic applications for the wine making (vinification), especially the ultrasound-assisted extraction, agglomeration, and dispersion have to be named. These impacts make sonication such an effective processing method for wine and other beverages.

Literature/References

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Talk to us about your processing requirements. We will recommend the most suitable setup and processing parameters for your project.

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