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IMPLEMENTATION OF THE WINE SAFETY MANAGEMENT SYSTEM IN THE CONDITIONS OF USING THE ULTRASOUND TREATMENT AS A PROCESS IN THE TECHNOLOGY OF OBTAINING RED WINES

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Abstract: *The primary goals of the food and beverage sector are to ensure production safety and provide safe food products. Numerous studies in the food industry confirm the current interest in various new technologies, including ultrasound treatment, which can lead to economical and high-quality products. The paper includes aspects related to the setting of the food safety management system in the perspective of using ultrasound treatment as a process step in the technology of obtaining red wines. The ultrasound treatment operation is a critical control point (CCP) due to the fact that there is a risk of damage to the acoustic amplifier (safety risk). This risk must be absent, and if damage to the acoustic amplifier is found, the batch of wine will be rejected from consumption or reprocessed.*
Key words: *Wine Safety Management System, ultrasound treatment, hazards and critical control points, wine industry.*

1. INTRODUCTION

Companies in the wine sector must plan, implement, operate, maintain and update a Wine Safety Management System (WSMS), in accordance with the principles of the Hazard Analysis and Critical Control Points (HACCP) of the Codex Alimentarius [1]. This WSMS consists of effective management procedures that ensure viti-vinicultural products are safe for consumers [2]. Food safety is one of the qualities that make up a food product's quality, which is generated by several of its own characteristics that are given to it during the production process. Assuring the protection of human life and health is one of the primary goals of European food legislation. This goal can be met by following rules and procedures that contain common principles relating to producers' obligations, structure, organization, and facility hygiene standards, storage and transport specifications, and hygiene markings [3].

The implementation of a HACCP system in a winery must always be accompanied by compliance with a prerequisites program (PRP) containing all the elements that can ensure wine safety or make up the hygiene system in a winery. It must also comply with processes of grape production according to Good Agricultural and Viticultural Practices (GAVP) and the International Organization of Vine and Wine (OIV) criteria, as well as the standards of the International Code of Oenological Practices of the OIV and of Codex Alimentarius [4]. The analysis of hazards based on the HACCP system can allow for risk assessment and determination of Critical Control Points as well as resulting actions [5].

Currently, there are several emerging technologies being used in winemaking. Some of these include: high hydrostatic pressure, ultrasounds, pulsed electric fields, pulsed light, UV irradiation, e-beam irradiation, ozone and electrolyzed water. These technologies destroy or strongly minimize the initial wild microbiota allowing for more hygienic winemaking processes [6 – 8].

Ultrasound is a physical technology that has been used to accelerate the extraction, freezing, filtering, dehydration and sterilization processes in the field of food processing [9]. In winemaking, ultrasound has been explored in several stages of the winemaking process and for different purposes such as to reduce the use of SO_2 in controlling the microbiological population in wine. Moreover, this technology could be used to accelerate wine aging on lees [10].

Ultrasound could also accelerate extraction and fermentation in winemaking. It might improve wine color, physicochemical and flavor characteristics [11]. Ultrasound works by producing high-frequency sound waves that create pressure changes in liquids. These pressure changes cause the formation, growth and violent collapse of small bubbles or voids in liquids. This process is known as acoustic cavitation [12], [13]. In winemaking, this can lead to the breakage of the cell walls of the grape skin and seeds, facilitating the release of compounds of interest into the medium [14].

The purpose of this work is to identify and specify the technical and managerial aspects generated by the implementation of ultrasound treatment at the level of a wine cellar.

2. METHODS USED

The analysis for the establishment of Preliminary Operational Programs (Good Manufacturing Practices - GMP and Good Hygiene Practices - GHP) focused on the description of mandatory practices and procedures and prohibited actions during winemaking. According to the HACCP methodology, a thorough examination of all major and supporting stages of wine production, from harvest to bottling, was done to identify any potential safety issues. The analysis for winemaking safety focused on all principles and included the following steps: defining the team, deploying the product and its intended use, description of the production processes, identifying all potential hazards (physical, chemical, and microbiological), developing preventative measures for the hazards introduced, and identifying CCPs with the necessary control and the relevant critical limits.

A comparable method of analysis is used to identify the relative quality crucial stages (critical points, or CPs), which occur at various points during the wine-making process. Table format is used to display the quality and safety outcomes.

3. RESULS AND DISCUSSION

The primary goals of the food and beverage sector are to ensure production safety and provide safe food products. These goals can be met by adopting an organized, systematic structure and managing resources, activities, processes, and procedures in accordance with the norms that serve as the foundation for quality and hygienic systems, such as Hazard Analysis and Critical Control Points (HACCP) and the ISO 9000 series. Implementing a Quality Management System refers to both the consolidation of regulatory requirements and the guarantee of quality procedures for food firms, as defined by the ISO 9000 series in the realm of food goods [15]. Therefore, employing Good Manufacturing Practices (GMP), HACCP, and the ISO 9001 family, businesses in the food industry can create a strong foundation in terms of quality [16].

The following conceptual map (Figure 1) briefly presents the way to achieve the objective of this paper.

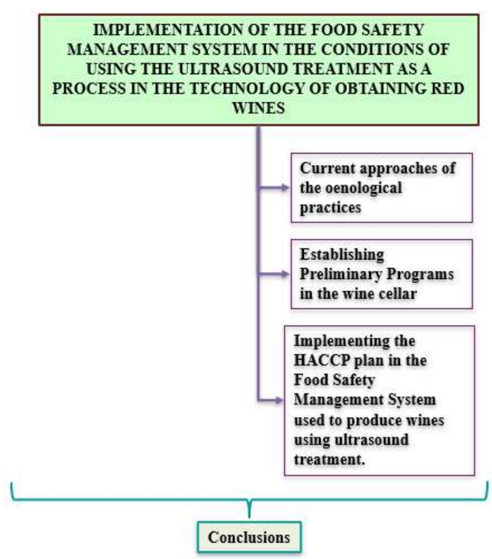

Fig. 1. Description of the methodology used in this investigation

3.1 Current approaches of the oenological practices

The International Organization of Vine and Wine (OIV) decided in 2019 to include the ultrasound treatment of crushed grapes to promote the extraction of their compounds in the International Code of Oenological Practices, noting that ultrasound is used as a treatment in the technological process of processing the grapes, more precisely during the maceration - fermentation stage [17].

The OIV also adopted a Guide for sustainable viticulture in 2008. It is advised that member states use this guide as a starting point when creating, revising, and/or updating national or regional procedures for viticulture that are environmentally sustainable, particularly in terms of grape production and processing as well as product packaging [18].

In addition, the OIV adopted in 2020 a Guide to identify hazards, critical control points and their management in the wine industry, which aims to harmonize the analysis of hazards and proposes as an example the level of risk and critical control points related to wine safety and hygiene requirements that may occur during the steps of winemaking [2].

3.2 Setting up Preliminary Operational Programs (Good Manufacturing Practices - GMP and Good Hygiene Practices - GHP) in the Winery

Operators in the food industry are required to follow both Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP), as well as HACCP-based procedures, as specified in the Appendices of Regulations 852 and 853, which are known as the *Preliminary Programs* [19], [20]. The basic requirements and actions needed both inside the firm and along the entire food supply chain are referred to as the preliminary programs. Personal hygiene, cleanliness, and disinfection are all part of GMPs, and depending on the particulars of the processing step, GMPs also cover the correct dosage of chemicals and keeping the right temperature [21].

Before using the HACCP-based processes, the owner of a food firm must first adopt the PRP. Moreover, a WSMS must also comply with the regulations of Regulation (EC) No. 178/2002, as this is a fundamental necessity.

Preliminary programs are implemented considering the context, the size of the winery and the activities carried out. These preliminary programs are established before the hazard analysis is carried out. For each operation in the technological flow of wine production, mandatory measures, and prohibited practices are established as follows (Table 1).

3.3 Implementing the HACCP plan in the Food Safety Management System used to produce wines using ultrasound treatment

Grapes, must, and wine are all subjected to significant quality and safety hazards during the winemaking process [1]. The crucial customer acceptability attributes of product appearance, taste, scent, color, alcohol concentration, and acidity are all related to quality hazards [23]. Physical dangers such as metal pieces, shards, and insects; chemical risks such as pesticides, heavy metal residues, and urea; and microbiological risks such as pathogens are all included under the heading of safety [23]. Environment, processing machinery, and vineyard staff can all pose risks [24]. The Hazard Analysis and Critical Control Points (HACCP) plan is a method for identifying and assessing the risks and hazards related to the production, storage, and distribution of food [2]. It then implements the necessary controls to eliminate or reduce these risks in the case of a particular production line points. The HACCP system's reduction of undesirable items is its main goal. The list of HACCP terminology is defined in the following:

Any biological, chemical, or physical element that poses an unacceptable risk to customer safety or product quality is considered a danger. Any location, person, activity, or protocol where insufficient control could lead to a food hazard is known as a critical control point (CCP). When there is an unacceptably high risk to the quality of the final product if this phase is not monitored, a risk becomes a critical control point (CCP) [25].

Table 1

Description of GMP and GHP in the wine industry.

Process stage	Mandatory practices and procedures	Prohibited Actions
Reception of grapes	It is necessary to request the certificate of guarantee of production origin. It is necessary to keep a record of each product received, such as grapes. Any solid waste that has stuck to the inside of the truck or to the crates must be placed in the proper containers after unloading. The truck or crates must be moved to a place where they can be washed, and the dirty water must be collected. Every time you unload something, you have to wash the trailer, the tarp and the crates. The garbage must be kept in a special container if a sorting table is used.	Never mix grapes of one variety/origin with grapes of another variety/origin.
De-stemming / Crushing	Bunches should be collected and stored directly in an airtight container to prevent spillage and ensure proper control.	NA
Ultrasound treatment	To improve the effectiveness of the treatment, it must be applied to crushed and destemmed grapes. This treatment must be carried out with the volume moving in order to avoid a temperature increase in the bulk of the crushed grapes. The bulk of the crushed grapes must have an appropriate solid/liquid ratio in order to effectively trigger the cavitation process.	NA
Maceration and alcoholic fermentation	The usage of SO_2 must be limited to the bare minimal amount technologically required while taking into account the legal restrictions [22].	Using yeasts that have been genetically modified (GMOs). Use of unlicensed gas cooling apparatus.
Pressing	Storage of pressed pomace in tightly sealed containers to avoid spills and proper control of their use in evaluation.	NA
Malolactic fermentation	After the malolactic fermentation is finished, utilize SO_2 only as much as is technologically necessary while taking into account any legal restrictions [22].	Use of genetically modified organisms (GMOs)-containing lactic acid bacteria.
Racking	At the end of the day, clean and sterilize the ducts.	NA
Clarification and cold stabilization	Clarifier byproducts and residues should be properly collected and controlled without spilling. After thermal stabilization, gather the crystals that have been left on the container walls and manage them appropriately. Gather and dispose of the cleaning agents used on the containers.	Making use of unlicensed refrigeration equipment.
Filtration	Avoid spilling runoff by collecting and controlling leftovers and filter byproducts (diatomaceous earth, cellulose layers).	NA
Botling and labeling	Use SO_2 only to the extent that is technologically essential, as described in legislation [22]. Control each waste product and byproduct produced by these processes (broken glass, cork, cardboard, caps, plastics, rolls, and torn labels) properly and independently. Use only official labels.	Use of caps containing more than 100 ppm of lead.
Oenological products usage	Use oenological products as directed and don't go above any dose limits imposed by laws or regulations that may be relevant [22]. According to their features, wine products should be stored in the best locations. Keep all items in their original packaging. Separate dangerous products from safe ones. Containers containing used wine goods should be stored and controlled correctly.	NA

* NA – NOT APPLICABLE

The following characteristics have to be monitored during ultrasonic processing: temperature and physical properties of the product, treatment time, frequency and power of ultrasound, and nature of the acoustic amplifier. When each PCC is identified, their objectives and constraints are defined. Then, to prevent the PCCs from being exceeded, a system of verification procedures will be implemented. This system collects control procedures and general hygiene measures that will be implemented in accordance with the defined goals. If the verification methods reveal that the PCC limit has been exceeded, remedial steps are implemented to meet the standards, and the effectiveness of these activities is re-evaluated.

Hazard evaluation and classification are carried out for each stage of the procedure, including the ultrasonic treatment. Preventive measures are designed for each hazard with the use of protocols that specify who will perform the activity, how, when, and where. The basic goal of preventive measures is to stop the hazard from happening. For example, a good maintenance schedule minimizes the possibility of metal contamination in the acoustic amplifier.

The caliber of the device, the settings employed, and the initial rate of microbial development in the product all affect how well ultrasound treatment works. Poor personal hygiene due to bad habits (contamination during handling), non-observance or inadequate observance of sanitation procedures, cross-contamination, abnormally high growth of microorganisms due to inadequate raw material storage conditions and/or non-compliance with supplier requirements are the main causes of microbial contamination.

Therefore, to maximize the preservation operation, preventive measures must be put in place. These measures include:

- Controls over the raw material supply and verification of the supplier's requirements;
- Controls over cleaning efficiency; chemical hazards must also be controlled in employee cleaning procedures; and
- Checking the ultrasound system's performance and its parameters.

For a product like wine, quality and safety are crucial, with quality control being crucial for consumer acceptance and safety assurance being essential for the preservation of the general populace's health. By addressing the risks at every stage of winemaking, beginning with grape harvest, wine safety may be guaranteed.

The scope and membership of the HACCP interdisciplinary team are defined in Table 2.

Table 2

HACCP multidisciplinary team's aims and structure.

Product	**Still red wine, from grapes treated with ultrasound after destemming and crushing**
Processes	From harvesting to delivery of the bottled wine
The HACCP team's membership may include, but is not limited to:	Team Leader Technologist Engineer (Production Specialist) Laboratory Engineer, Quality Assurance Specialist in product supply and marketing hygiene

Gathering information on the product and identifying its intended usage are deployed in Table 3.

Table 3

Information about the product and its intended use.

Product	**Still red wine, from grapes treated with ultrasound after destemming and crushing**
Regulatory standards to be met	Product definition as specified in Art. 16, HG 512/2016; Authorized oenological practices and treatments as specified in Chap. IV H.G. 512/2016; The quality of wines as specified in Section 4, HG 512/2016; Marketing of wine as specified in Section 1, Ch. V, HG 512/2016
Used packaging	Bottle sealed with cork or other internationally accepted materials, with paper wrapping; bottles packed in cartons
Labeling	Mandatory information: the name of the category of wine products; for D.O.C. or I.G. wines: the words “controlled denomination of origin” or “geographical indication” and the controlled denomination of origin or geographical indication; acquired alcoholic strength; the country of origin; the name of the bottler; the type of wine according to the sugar content; the nominal volume of the container; the batch number to identify the bottling date; the terms sulphites or sulphur dioxide, eggs, egg proteins, egg products, egg lysozyme or egg albumin, milk, milk products, milk casein or milk protein or the corresponding pictograms, where applicable.
Storage and distribution	Store in a dark, moderately humid place at 12-13 °C
Consumers and intended use	Adults, ready to eat

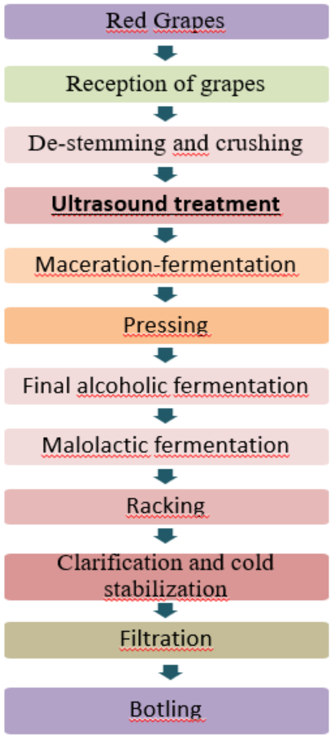

Fig. 2. Flow chart of the red winemaking process using ultrasound treatment as a process step.

Description of the production process and on-site verification of the flowchart (Figure 2) is based on a generic process that includes most of the common steps involved in wine production.

The findings of an investigation of safety concerns during the various stages of wine production are shown in Table 4. The analysis was created in line with HACCP principles, outlining hazards and suggesting ways to avoid them while also mentioning any potential critical elements, their critical limits, or crucial control actions. The identification of critical control points (CCPs) with the required control methods and related critical limits was the main goal of the safety analysis of wine production. The relative key stages for quality (critical points - PC) were determined using a similar strategy for quality hazards during wine processing. The most crucial elements and accompanying control measures are described for each CCP or PC stage. The application of the OIV Guide for Viticulture (CST 1/2008) [18] and the GMPs are part of all preventive measures.

Table 4

Analyzing risks, identifying crucial points, and defining the monitoring system (per process stage).

Proc	Safety risks	Quality risks	Preventive actions	Hazard treatment	Monitoring
Reception of grapes	Metals, chips, plastic, insects, earth, string, fungicides, insecticides, milk of lime + $CuSO_4$, fertilizers, wastewater	Yeasts, molds: *Botrytis Cinerea, Botryotinia, Leuconostoc dextranicum*, Bacteria: *Acetobacter*	Strict compliance with maximum pesticide residue levels	CP	Chemical and microbiological analyses in internal and external laboratories. Sugar content: minimum 200-250 g/l. Acidity: 4,5-5 g/l, density, mass of 1000 grains, identification of variety, determination of biological state, weighing, degree of attack by rust and microorganisms.
De-stemming / Crushing	Contamination of grapes and must be due to inadequate cleaning (residues of microorganisms, traces of cleaning). Foreign matter in grapes and must from equipment (metal parts, grapes)	Bunch residues. Grape contamination with Botrytis cinerea Increase of pulp content in the must	Grubbing equipment maintenance Manual removal of foreign matter from grapes Use of SO_2 to prevent grape spoilage. Proper cleaning of the opener with cold water	CP	Manual removal of moldy grapes. Control of the cleaning of the extractor. SO2 measurement of grapes (sulfidation with doses between 50-120 mg/L). Retention time of the must in the crusher < 2 hours. Must and grape weight

Ultrasound treatment	Damaging the acoustic amplifier	Temperature, ultrasonic frequency, ultrasonic power, flow rate	Application of OIV Decision 616-2019 on ultrasonic treatment of crushed grapes to promote extraction of compounds	CCP - Damage to the acoustic amplifier- ABSENT Reduce ultrasonic duration and/or amplitude for temperature control. Batch rejection or reprocessing	Acoustic Amplifier Integrity. T: 60 °C maximum; Frequency: 20 kHz Determination of polyphenol content, color indices (color intensity, hue)
Maceration-fermentation	Detergents, CO2, nitrogen tannins, pectics	Microorganisms, yeasts, bacteria, molds, yeasts		CP	T: maximum 25 ºC, high CO_2 release, duration 3-7 days, alcoholic strength: 7-9% vol. alcohol, d: 1,006-1,010 kg/m^3, determination of color indicators (color intensity, hue)
Pressing	Foreign matter in must from press Wort contamination from cleaning residues	Strong sensory characteristics of the must Deterioration of must quality due to prolonged pressing Increase in the number of tannins	Fast passage through the pressing process Cleaning of pressing equipment	CP	Measurement of tannins and must acidity Weighing the pomace and determining the quantity of wine Checking the cleaning of the pressing equipment
Final alcoholic fermentation	Production of ethyl carbamate Residues of cleaning agents in fermenters Residues of pre-fermentation additives (yeast, bentonite) Excessive addition of SO_2 to fermented wort	Development of unwanted bacteria in the fermenter Blocked fermentation Loss of wine aromas Production of H2S and acetic acid Oxidation due to oxygen in the fermenter Lactic fermentation of sugars, glycerin, tartaric acid Increase in wine viscosity	Use of SO_2 to prevent wine spoilage Application of recommended SO_2 limits Inoculation of selected yeast strains Use of automatic cooling systems to maintain temperature in the fermentation zone Stable fermentation temperature Repumping Fermenter cleaning and disinfection	CP	Fermentation temperature: 18ºC -20ºC Must aeration during the first 48 hours of fermentation Control of yeast inoculation Recommendation SO_2 < 200mg/L must Control of the pumping process Monitoring of must density during fermentation, alcohol content, sugar content Duration 1-3 weeks
Malolactic fermentation	CO_2, SO_2	Increase the pH of the wine. Decrease the acidity of the wine. Impairment of wine flavor.	Inoculation of malolactic yeast	CP	Wine pH monitoring; pH: 3.2-3.8 Wine acidity monitoring Temperature control T: maximum 20 ºC SO_2 monitoring

Racking	Foreign matter in tanks (sediment) Cleaning agent residues	Potassium bitartrate deposits Revitalization of yeasts Oxidation of the wine. Growth of spoilage microorganisms.	Cleaning the cellar Transfer to clean tanks. The second transvasation of winter The third transvasation in spring. Removal of air from tanks during fermentation. Adding SO_2 to the wine	CP	Control of tank cleaning processes Control of winery cleaning processes Control of tartaric stabilization Stabilization time: minimum possible Control of the filling of the tanks at the time of transvasation SO_2 monitoring
Clarification and cold stabilization	Adding impurities to wine Residues of detergents Traces of dangerous metals in wine (Pb, As, Cu) Chemical residues in wine	Yeast residues Foreign matter in wine from adsorbents Turbidity of the wine	Addition of legally approved substances Addition of clarifiers with dosing pumps Dissolving clarifiers in water Rapid removal of yeast from wine Addition of legal substances to stabilize wine Adding SO2 to prevent spoilage Storing wine away from air and light Application of bentonite	CP	Bleach solutions, bleach residues, yeast residues Measurement of metal limits (As < 0.01, Cu < 0.1, Pb < 0.3 mg/L wine) Additive release control Measurement of oxidases in wine Microscopic analysis of wine Fe^{+2} < 12 mg/L wine Cu^{+2} < 3 mg/L wine
Filtration	Contamination of the wine by filters (residues of detergents, microorganisms, sediments) Foreign matter from filters	Appearance of filter taste in wine	Sanitizing Filters (Cleaning Procedures) Use appropriate filters Use of clean filters Filter maintenance	CP	Control of filtration hygiene practices (cleaning procedures, environment) Control of hazardous materials in filters Control of filter cleaning procedures Control of filter integrity
Botling	Foreign matter in wine from bottles and bottling line Cleaning agent residues in wine	Microorganisms causing undesirable changes in wine Mold growth in wine bottles Wine leaking from bottles Loss of sensory characteristics of wine due to oxidation	Bottle Cleaning Bottling line sanitization and disinfection Winery sanitization and disinfection Chemical and mechanical bottle cleaning Adding SO_2 to wine before bottling Removal of air from wine with N2	CCP Foreign matter in wine from bottles-ABSENT Bottle rejection	Bottle cleaning procedures Control of hygiene measures for the bottling line, the environment and the bottles Microbiological control of bottling line, bottles and environment Control of bottle cleaning procedures Visual and microbiological inspection of bottles

4. CONCLUSIONS

Ultrasound treatment is an additional technological operation that must be incorporated into the wine cellar's technological flow. The quality risks to which grapes, must, and wine are exposed during technological operations include the product's appearance, taste, aroma, color, alcohol content, and acidity, while safety risks to consumers' health include metal parts, shards, insects, pesticides, heavy metal residues, urea, and pathogens. In terms of safety criteria, the presence of foreign materials, pesticide residues, and microbiological load must all be controlled when grapes are received, as these all-pose threats to consumer health.

The ultrasound treatment procedure is a critical control point (CCP) because there is a possibility of acoustic amplifier damage (safety risk). This risk must be eliminated, and if acoustic amplifier damage is discovered, the batch of wine will be rejected for consumption or reprocessed.

In terms of quality criteria, temperature control is required during the maceration, fermentation, and maturation processes. Microorganism development should be monitored throughout the mixing stage, and the lack of air should be managed during maturation. Microbiological monitoring of bottles and corks is required during the bottling process. Quality and safety are critical for a product like wine, with quality control throughout the entire process being critical for consumer acceptability and maintaining safety being required for public health protection. Wine safety can be ensured by addressing the aforementioned risks throughout the winemaking process, beginning with grape reception.

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Implementarea sistemului de management al siguranței vinului în condițiile utilizării tratamentului cu ultrasunete ca etapă de proces în tehnologia obținerii vinurilor roșii

Obiectivele principale ale sectorului alimentar și al băuturilor sunt asigurarea siguranței producției și furnizarea de produse alimentare sigure. Numeroase studii din industria alimentară confirmă interesul actual pentru diverse tehnologii noi, inclusiv tratamentul cu ultrasunete, care poate duce la produse economice și de înaltă calitate. Lucrarea cuprinde aspecte legate de setarea sistemului de management al siguranței alimentelor în perspectiva utilizării tratamentului cu ultrasunete ca pas de proces în tehnologia de obținere a vinurilor roșii. Operatia de tratament cu ultrasunete este un punct critic de control (CCP) datorita faptului ca exista riscul de deteriorare a amplificatorului acustic (risc de siguranta). Acest risc trebuie să fie absent, iar dacă se constată deteriorarea amplificatorului acustic, lotul de vin va fi respins de la consum sau reprocesat.

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