



## An evaluation of sustainability in wineries based on their performance in compliance with food safety.

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### Abstract:

Agri-food industry is confronted with a significant challenge concerning the requirement for sustainable food production methodologies. Companies within the agrifood sector encounter both challenges and prospects, such as the integration of responsible agricultural practices, mitigation of environmental impact, and enhancement of working conditions. This research pertains to the employment of metrics as a means of assessing sustainable practices, specifically in reference to food safety performance indicators. Wine production is employed as a dual case study to assess the efficacy of wineries in managing critical control points (CCPs). The first aspect focuses on CCP system, as a component of a food safety system based on pre-requisite programs (PPRs) and hazard analysis and critical control points (HACCP). The second aspect specifically addresses the performance in the risk of contamination by arsenic, cadmium, and lead CCP during wine production. The first study showed that wineries have poor control performance for 15 out of the 37 CCPs evaluated, and the worst control performance seems to be related to chemical controls of trace metals, fungicides, and pesticides in grapes or wine, biological controls of microorganisms on equipment, and controls in the operational stage. The second investigation analyzed the performance of wineries in controlling the CCP related to the risk of contamination by arsenic, cadmium, and lead during wine production. The results showed that wineries are failing in the areas of analysis and legislation. Using performance indicators of training, legislation, and physical-chemical analysis can serve as a qualitative measure of progress in implementing food safety systems in wineries.

**Palabras clave:** beverages; HACCP; food safety; wine; sustainable production

### 1. Introduction

Currently, it is observed that agricultural and food production is not being carried out sustainably [1]. According to the European Commission, food production continues to have a negative impact on the environment of the European Union (EU), while 20% of produced food is wasted. Although agriculture in the EU has made significant progress in reducing greenhouse gas emissions and nitrate levels in rivers since 1990, there is still much to be done throughout the entire food chain [2]. Therefore, it is necessary to propose a new framework for food production and processing at the industrial level, in line with sustainability principles.





It is essential to develop food production methods that are compatible with the conservation of the environment. In other words, it is imperative to implement agro-industrial production methods that minimize the impact on ecosystems and natural resources, while ensuring food safety and healthy nutrition for consumers [3].

Sustainability in the agri-food industry is still in its early stages. Numerous studies have provided perspectives on the challenges and opportunities faced by companies in the agri-food sector. However, due to the growing complexity of this field, it is necessary to develop more systematic approaches that include sustainability [4]. It is imperative to implement responsible agricultural practices, reduce environmental impact, and improve working conditions. These measures can contribute to the conservation of natural resources, improve the quality of the final product, and promote the economic development of local communities.

Often, the approaches used in the agri-food industry do not simultaneously achieve these objectives, which can generate negative effects such as lack of food safety or serious environmental impacts. Food or ecosystem contamination, food poisoning derived from deficient agro-industrial practices, the use of chemicals in agro-industrial production processes, are some examples of this reality.

Gold et al. [5] specified the dimension of sustainability through indicators such as local living conditions, labor rights, land rights, food security, valorization through biomass recycling, and environmental issues. In this context, food security is a useful indicator within the sustainability dimension to analyze the sustainability performance of the agri-food supply chain.

Wine production is an integral part of the food chain and is closely related to the sustainability of the food chain. Wine production involves the cultivation of grapes, the transformation of grapes into wine, and the distribution and commercialization of the final product [6]. It is a fact that wine production presents risks to food safety. Wineries have implemented food safety management systems to control food risks through Hazard Analysis and Critical Control Points (HACCP). The wine industry applies HACCP by evaluating Critical Control Points (CCP). A Hazard Analysis and Critical Control Points (HACCP) system allows identifying, assessing, and controlling significant food safety risks throughout the entire wine production process.

## 2. Materials and methods

A first investigation analyzed the Prerequisite Programs (PPRs) and the performance of HACCP in the wineries with Protected Designation of Origin "Vinos de Madrid". The performance of wineries was evaluated for each critical control point (CCP) at each stage of the wine production process, including the implementation of PPR and HACCP principles. This study was carried out through a survey of 55 questions divided into 11 sections and was conducted on a sample of 21 wineries.

A second investigation selected one of the CCPs identified as poorly controlled. This CCP is the risk of contamination by arsenic, cadmium, and lead during wine production. The level of performance of wineries in controlling CCPs related to the risk of contamination by arsenic, cadmium, and lead in wine production was analyzed through a sixteen-question questionnaire that was administered to a sample of 32 wineries from all the Protected Designations of Origin in Spain. Subsequently, three indicators were calculated for the performance components of training, legislation, and analysis in controlling this CCP.

## 3. Results and discussion

The results of the first investigation determined that performance control for each of the 37 evaluated CCPs during wine production is different (see **Table 1**). A total of 22 CCPs are well-





evaluated by wineries. However, there are significant differences among the other 15 CCPs depending on each winery. The worst control performance among wineries for CCPs seems to be related to chemical controls of trace metals, fungicides, and pesticides in grapes or wine, biological controls of microorganisms on equipment, and controls in the operational stage such as remaining time of must in crushers [7].

**Table 1.** Contingency table of the medians of each variable associated to each evaluated CCP.

Winemaking Steps	Variable/Critical Control Point (CCP)	Frequencies				High Variability
		Always (3)	Usually (2)	Hardly Ever (1)	Never (0)	
1. Harvest and grape transportation	VAR1.1 Grape inspection previous harvest in vineyards.	█				Y
	VAR1.2 Grape inspection during harvest in vineyards.	█				
	VAR1.3 Transportation time of harvest from vineyards to winery.	█				Y
2. Harvest reception in the winery	VAR2.1 Presence of fungicide residues and/or pesticides in grapes.			█		Y
	VAR2.2 Presence of mycotoxins from grape rot.	█				
	VAR2.3 Contamination by metals (Cadmium, Lead, Arsenic) in grapes.				█	Y
	VAR2.4 Contamination by plant residues, dust and/or metal elements.	█				
3. Pre-hatching treatments	VAR3.1 Vat cleaning to eliminate residues of microorganisms.	█				
	VAR3.2 No residues of cleaning and disinfection products in vats.	█				
4. Grapes crushing and must pumping	VAR4.1 Time that remains the must in the crusher after crushing.				█	Y
	VAR4.2 Cleaning of crushing equipment.	█				
	VAR4.3 No residues of cleaning and disinfection products in vats.	█				
5. Sulphited and vatted	VAR5.1 Safety and purity of the additives.		█			Y
	VAR5.2 No microorganisms in equipment and vats.	█				
6. Alcoholic fermentation, maceration, vat emptying, pressing, malolactic fermentation	VAR6.1 Concentration of ethylcarbamate in fermented must.		█			Y
	VAR6.2 Concentration of sulphur dioxide in fermented must.	█				
	VAR6.3 Purity and safety of yeasts.	█				Y
	VAR6.4 Temperature during fermentation.	█				
	VAR6.5 pH of red wine during malolactic fermentation.	█				
	VAR6.6 Hygiene during vat emptying/pressing operations.	█				
	VAR6.7 Cleaning of pressing equipment.	█				Y
7. Racking, clarification, and filtration	VAR7.1 Cleaning procedures for vats and racking equipment.	█				
	VAR7.2 Maintenance and cleaning of the facilities during racking.	█				
	VAR7.3 Purity and safety of agents used as clarifiers of the wine.	█				Y
	VAR7.4 No residues of clarifiers in the wine.		█			Y
	VAR7.5 No weird elements from filters in the wine.	█				
	VAR7.6 Hygiene during clarification and filtering operations.	█				
	VAR7.7 No residues of cleaning and disinfection products in vats.	█				
8. Cold stabilization	VAR8.1 Limit concentrations of metals (traces of As, Cu, Pb) in the wine.			█		Y
	VAR8.2 Additives accepted by current food legislation.	█				
9. Bottling and labelling	VAR9.1 Bottle cleaning procedures.		█			Y
	VAR9.2 Cleaning procedures of the bottling line.	█				
	VAR9.3 No microorganisms in the bottling line.			█		Y
	VAR9.4 No microorganisms in bottle cap.	█				Y
	VAR9.5 Correct coding of the label used on the bottles.	█				
	VAR9.6 Correct description of allergen information on bottle labels.	█				
	VAR9.7 Correct description of P.D.O. information on bottle labels.	█				





Poorly controlled CCPs assume that hazards such as the appearance of microorganisms, trace metals, fungicides, pesticides, or other hazardous products in grapes or wine can occur [8-10].

The second research showed that wineries are failing in the areas of analysis and legislation of the risk of contamination by arsenic, cadmium, and lead CCP during wine production. The identification and updating of legislation regarding the risk of contamination by As, Cd, and Pb is at an initial performance level for wineries that produce less than 250,000 L/year. The performance level of analysis is even lower than that of legislation. One in three wineries has information on the concentrations of arsenic, cadmium, and lead in the soils of the vineyards where the grapes come from, and this rate is even lower for their concentration available in the soil solution. Wineries that monitor the concentrations of As, Cd, and Pb do so according to official recommendations using techniques based on atomic absorption spectrometry. However, there is a lack of spectrometry equipment in the winery laboratories themselves.

The second research allowed the design of three performance indicators based on the responses obtained from wineries [11, 12]. Wineries were distributed in five groups according to their yearly wine production to calculate them. Performance indicators allow to determine the degree of progress wineries had reached related to the control they conduct on the contamination risk of arsenic, cadmium, and lead in grapes and wines. Components performance level by each winery sizes production level on the contamination risk by arsenic, cadmium, and lead in wines are showed in **Table 2**.

**Table 2.** Wineries performance indicators and grade of progress, by type of winery.

Wineries size	$I_{fswt}$	Grade of progress	$I_{tiu}$	Grade of progress	$I_{ccp-Mchem}$	Grade of progress
Up to 25,000 L/year	0,89	Maturity	0,44	In progress	0,05	Start
25,001-100,000 L/year	0,77	Maturity	0,15	Start	0,08	Start
100,001-250,000 L/year	0,78	Maturity	0,28	Start	0,51	In progress
250,001-1,000,000 L/year	0,94	Maturity	0,66	In progress	0,56	In progress
More than 500,000 L/year	0,93	Maturity	0,60	In progress	0,42	In progress

#### 4. Conclusions

This work demonstrates the need to continue improving in the technical implementation of the HACCP methodology and in training workers about food safety in wineries. Establishment of new CCPs surveillance formats involving the different professionals working in the wineries (enologist, manager, winery operators, quality managers) will improve performance in the CCPs surveillance, and by extension, the deployment level of the entire HACCP. A good implementation of PPR and HACCP contributes to eliminating food safety risks that compromise people's health, being the basis for the development of sustainability based on the food safety indicator.

Also, wineries must adequately control the risk of arsenic, cadmium, and lead contamination in the wine production process. To do it, first, wineries must be aware of the need to know, update and implement European legislation. European legislation sets the guidelines to prevent health risks that may arise from the intake of arsenic, cadmium, or lead by setting limits on the admissible concentration of these metals in wines. In addition, wineries'





workers' training in GMP and CCPs control is a success factor in preventing contamination by arsenic, cadmium, and lead in wines.

Moreover, the performance indicators of training, legislation, and physical-chemical analysis performance, developed through the analysis of the implementation of the CCP, serve as a qualitative measure of the progress in the three performance dimensions related to the implementation of food safety systems. This approach can be extended to all CCP system in wine production, thus becoming a qualitative method for evaluating the sustainability of wineries.

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