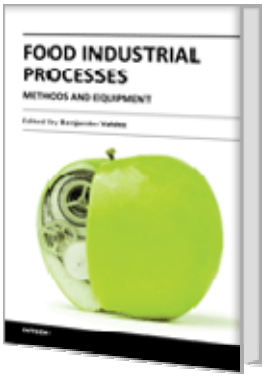
Food Industrial Processes - Methods and Equipment



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The global food industry has the largest number of demanding and knowledgeable consumers: the world population of seven billion inhabitants, since every person eats! This population requires food products that fulfill the high quality standards established by the food industry organizations. Food shortages threaten human health and are aggravated by the disastrous, extreme climatic events such as floods, droughts, fires, storms connected to climate change, global warming and greenhouse gas emissions that modify the environment and, consequently, the production of foods in the agriculture and husbandry sectors. This collection of articles is a timely contribution to issues relating to the food industry. They were selected for use as a primer, an investigation guide and documentation based on modern, scientific and technical references. This volume is therefore appropriate for use by university researchers and practicing food developers and producers. The control of food processing and production is not only discussed in scientific terms; engineering, economic and financial aspects are also considered for the advantage of food industry managers.

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Preface

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Food shortages threaten human health and are aggravated by the disastrous, extreme climatic events such as floods, droughts, fires, storms connected to climate change, global warming and greenhouse gas emissions which modify the environment and, consequently, the production of foods in the agriculture and husbandry sectors.

This well-organized volume includes twenty-two chapters, divided into three parts:

- Physical and chemical features
- Biotechnological aspects
- Industrial processes

This collection of articles is a timely contribution to issues relating to the food industry; they were selected for use as a primer, an investigation guide and documentation based on modern, scientific and technical references. This volume is therefore appropriate for use by university researchers and practicing food developers and producers.

The book begins with an overview of physical and chemical properties of food such as hydrocolloids, which improve food texture, potential antioxidants from tropical plants, and the application of corrosion resistant stainless steel for fabrication of food processing equipment. The book then looks at the biotechnological aspects of food, for example electrochemical biosensors for food quality control, microbial peptic enzymes in the food and wine industry, and the effect of mycotoxins in food. Particular emphasis is placed on the methods and regulations to ensure the high quality of food. The food industry is in continuous evolution; the methods used to process the different types of food are developed to cover global needs and conditions. People worldwide have followed a basic diet of traditional foods; nevertheless, in the industrialized cities they tend to consume processed and packaged foodstuffs for convenience and to save time. The book concludes with a helpful section on industrial processes such as advanced oxidation processes, membranes for separation process in

wastewater from food processing plants and, last but not least, how to ensure the efficient plant operation and maintenance applying corrosion prevention and control with modern technology.

The control of food processing and production is not only discussed in scientific terms. Engineering, economic and financial aspects are also considered for the advantage of food industry managers. The application of computer-based online procedures and protocols to control sterilizing operations, heat transfer processes, canning and packaging of solid and liquid foods or the use of freezing and no freezing ice-temperature for conservation of freshness in meats and vegetables products which are all described in this book are interesting examples of the implementation of advanced technological developments in the food industry.

Finally, it is our duty and pleasure to acknowledge the valid information presented in the authors' chapters and the production of such a worthwhile compendium.

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Electrochemical Biosensors for Food Quality Control

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1. Introduction

The electrochemical biosensors are analytical devices designed by coupling biological recognition elements and electrochemical transducers. The transducer converts the analytical signal produced as a result of the biochemical and electrochemical interactions into measurable electrical one (Thévenot et al., 1999).
The electrochemical biosensors are self-contained, simple to handle, and able to provide specific, sensitive, accurate and cost-effective *in situ* and *on line* measurements in real time, without or with a minimum sample preparation. Because of these advantages over the conventional analytical methods, they are well suited for the detection of a large spectrum of compounds, entering food and subjects of analytical control.
The present work is intended to demonstrate the applicability of the electrochemical biosensors for arsenic determination in beverages.

2. Arsenic content in food and beverages

Arsenic is a chemically active, toxic, and carcinogenic element (Moore & Ramamoorthy, 1984). It is among the 129 priority pollutants of the environment and among the 25 hazardous substances representing a significant potential threat to human health (EPA: Toxic and priority pollutants). It occurs naturally in soil and groundwater, but additionally enters the environment in a large quantity because of the human industrial and agricultural activities. The most affected by arsenic pollution are fishes and other aquatic organisms, since they accumulate it. High arsenic concentrations in plants are registered when using for irrigation arsenic-rich groundwater or contaminated water because of the industrial discharges and the treatment of soils with fertilizers and pesticides. Lead arsenate insecticides were extensively used in some countries until 1981 (Peryea, 1998). Arsenic content in food from plant and animal origin, with the exceptions of seafood and animal and poultry offal, does not habitually exceed 0.25 mg kg^{-1}, according to WHO data (Arsenic.

WHO Food Additives Series 18). The average daily arsenic intakes for various countries are summarized in Fig. 1. Arsenic concentration in food and beverages, as evaluated by the US Food and Drug Administration (FAD, 2010) in its annual Total Diet Study, is shown in Table 1.

Product	As, mg kg^{-1}
Cheese, American, processed	0.002
Beef roast, chuck, oven-roasted	0.001
Turkey breast, oven-roasted	0.004
Liver (beef/calf), pan-cooked w/oil	0.001
Fish sticks or patty, frozen, oven cooked	0.527
Peanut butter, creamy	0.013
Peanuts, dry roasted, salted	0.014
Rice, white, enriched, cooked	0.065
Oatmeal, plain, cooked	0.002
Cream of wheat (farina), enriched, cooked	0.001
Corn, fresh/frozen, boiled	0.001
Bread, white, enriched	0.001
Bread, whole wheat	0.002
Muffin, fruit or plain	0.007
Corn/tortilla chips	0.001
Fruit-flavoured cereal, presweetened	0.013
Raisin bran cereal	0.006
Crisped rice cereal	0.135
Granola w/raisins	0.021
Oat ring cereal	0.028
Pear, raw (w/peel)	0.001
Strawberries, raw/frozen	0.001
Fruit cocktail, canned in light syrup	0.002
Grapes (red/green), raw	0.003
Cantaloupe, raw/frozen	0.008
Raisins	0.014
Avocado, raw	0.001
Apple juice, bottled	0.005
Prune juice, bottled	0.004
Spinach, fresh/frozen, boiled	0.001
Collards, fresh/frozen, boiled	0.003
Tomato, raw	0.001
Tomato sauce, plain, bottled	0.001
Cucumber, peeled, raw	0.011
Brownie	0.006
Syrup, chocolate	0.001
Jelly, any flavour	0.002
BF, cereal, rice, dry, prepared w/water	0.041
Beef steak, loin/sirloin, broiled	0.001
Chicken thigh, oven-roasted (skin removed)	0.009
Catfish, pan-cooked w/oil	0.012
Fruit juice blend (100% juice), canned/bottled	0.005

Lettuce, leaf, raw	0.002
Beef w/vegetables in sauce, from Chinese carry-out	0.004
Potato, baked (w/peel)	0.002
Chili con carne w/beans, canned	0.003
Quarter-pound hamburger on bun, fast-food	0.001
Meatloaf, beef, homemade	0.001
Chicken potpie, frozen, heated	0.001
Soup, tomato, canned, cond., prepared w/water	0.003
Cake, chocolate w/ icing	0.013
Sweet roll/Danish pastry	0.001
Gelatine dessert, any flavour	0.001
Wine, dry table, red/white	0.010
BF, beef and broth/gravy	0.001
BF, macaroni, tomato and beef	0.002
BF, peaches	0.001
BF, juice, apple	0.022
BF, vanilla custard/pudding	0.002
BF, fruit dessert/pudding	0.003
Chicken breast, oven-roasted (skin removed)	0.004
Shrimp, boiled	0.265
Bread, cracked wheat	0.003
Bagel, plain, toasted	0.001
English muffin, plain, toasted	0.001
Crackers, graham	0.004
Grape juice, frozen conc., reconstituted	0.007
Mushrooms, raw	0.073
Eggplant, fresh, peeled, boiled	0.001
Okra, fresh/frozen, boiled	0.001
Beef stroganoff w/noodles, homemade	0.012
Tuna noodle casserole, homemade	0.164
Fish sandwich on bun, fast-food	0.380
Egg, cheese, and ham on English muffin, fast-food	0.002
Clam chowder, New England, canned, cond., prepared w/ whole milk	0.128
Coffee, from ground	0.0002
BF, teething biscuits	0.004
Salmon, steaks/fillets, baked	0.288
BF, cereal, rice w/apples, dry, prepared w/water	0.033
Chicken breast, fried, fast-food (w/skin)	0.013
Chicken leg, fried, fast-food (w/skin)	0.013
Tuna, canned in water, drained	1.00
Cranberry juice cocktail, canned/bottled	0.004
Sweet potatoes, canned	0.001

Table 1. Arsenic occurence in food (US Food & Drug Administration - Total Diet Study - Market Baskets 2006-1 through 2008-4).

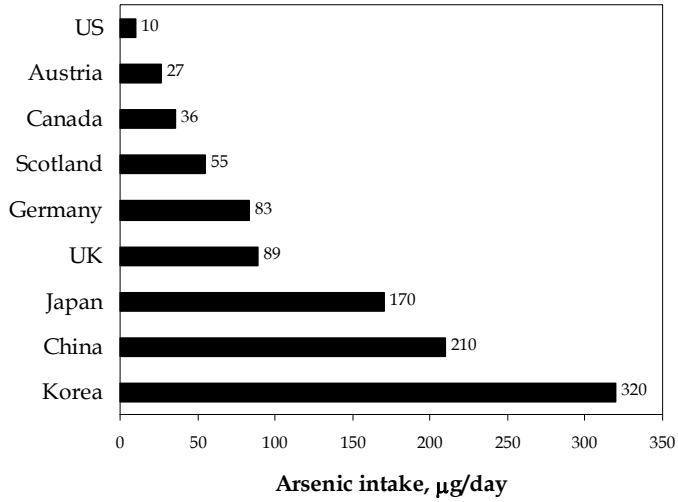

Fig. 1. Average daily arsenic intakes for various countries (Arsenic. WHO Food Additives Series 18)

3. Sample collection, preparation and treatment for arsenic determination in food and beverages

Sample collection, preparation and treatment for arsenic determination in food and beverages are performed according to the established procedures (WHO, 2011). These include: collection of samples, representative of the food consumed in a population; sample conservation in acid washed plastic containers; freezing of samples if necessary, to -80^{o}C; food preparation or cooking in a manner similar to those that would be used at home, if appropriate; sample homogenization and digestion, applying various techniques guided by the subsequent analysis technique.

4. Methods for inorganic arsenic determination in food and beverages

Inorganic arsenic determination could be performed applying a number of methods (WHO, 2011). Some of them, such as the spectrophotometric analysis with silver diethyldidhiocarbamate and certain modifications of the atomic absorption spectrometry (AAS) and the inductively coupled plasma (ICP) are standardised (DIN 38405-D12; APHA/AWWA/WPCF 3500-As C; AOAC 33.125-33.132 in combination with 25.041 and 25.042; EPA 7061; DIN 38405-D1; APHA/AWWA/WPCF 3500-As B: 3114 B; APHA/AWWA/WPCF 3500-As E: 3120 B; DIN 38406-E22) and are among the mostly applied for arsenic determination in food and beverages (Bingöl et al., 2010; Conklin, 2010; Husáková et al., 2007; Karadjova et al., 2005; Niu Jianjun & Wang Bingwu, 1992; Roberge et al., 2009; Stafilov et al., 2004; Syr-Song Chen et al., 2003; Tašev et al., 2005). Nevertheless, arsenic is one of the few elements for which AAS is not enough sensitive. Using special supplies such as arsine generators and electrothermal analysers allows lowering the detection limit, but causes difficulties in the routine analysis. The other advanced instrumental methods such as ICP, neutron activation analysis (NAA), and X-ray

fluorescence permit the determination of arsenic at trace levels, but they require expensive and sophisticated equipment. The spectrophotometric methods, although simple and cost effective, do not provide the required sensitivity.

The electrochemical methods for inorganic arsenic determination (Cavicchioli et al., 2004), including mainly anodic stripping voltammetry and differential pulse polarography, in spite of their limited application in food quality control, could be considered as an alternative to the above mentioned analytical techniques. For instance, their sensitivity is similar to this of mass spectrometry and NAA, but they are much more simple, require low costing equipment, and allow distinguishing the electro-active As(III) and the electro-inactive As(V), in contrast to the enumerated techniques. As(III) and As(V) have different toxicity, biological activity, and physiological action. The toxicity of As(III) is known to be greater of that of As(V). Thus, the distinction between the two forms is of primary importance.

The further development of the electrochemical methods is associated with the appearance, during the 1960s, of the so-called electrochemical biosensors. They combine the high sensitivity, accuracy and reproducibility of the electrochemical analysis with the substrate specificity and catalytic activity of the biological molecules. A number of them found an application in food industry, namely in food safety and quality control, and in the control of the fermentation processes (Mutlu, 2010; Scott, 1998; Prodromidis & Karayannis, 2002; Wagner & Guilbault, 1994).

5. Acylcholinesterase based sensor for arsenic determination in wine

Arsenic determination in wine, using the suggested in this work acetylcholinesterase electrochemical sensor, is based on the following reactions:

$$\text{acetylthiocholine} + H_2O \xrightarrow{ACh} \text{thiocholine} + CH_3COOH$$

$$\text{thiocholine} \rightarrow \text{dithio-bis-choline} + 2H^+ + 2e^-$$

The acetylcholinesterase Ach (EC 3.1.1.7) catalysed hydrolysis of acetylcholine generates the electroactive product thiocholine. The current of its oxidation is recorded amperometrically at a potential of +0.80 V/SCE. In the presence of As(III), because of the enzyme inhibition that it provokes, the quantity of the produced thiocholine decreases. Thus, the current of its oxidation also decreases as a function of As(III) concentration under similar conditions.

The acetylcholinesterase based electrochemical sensor was prepared as described in our previous works (Stoytcheva et al., 1998a, 1998b), i. e.: acetylcholinesterase was covalently immobilized onto the surface of a rotating disc electrode elaborated from spectrally pure graphite (Ringsdorf Werke, Germany). The analysis was carried out in an electrolysis cell of conventional type, at a temperature of 25^{o}C, with a rotation speed of the working electrode of 1000 rpm. The auxiliary electrode was a glassy carbon electrode. A saturated calomel electrode was used as a reference.

The response of the biosensor was measured for various acetylthiocholine iodide concentrations in the presence of different amounts of As(III) in the form of AsO_3^{3-} in a Britton-Robinson buffer solution with pH 7. The obtained results are presented in Fig. 2, where ΔI is the difference between the registered steady-state currents of thiocholine oxidation in the absence and in the presence of inhibitor (to note that iodide oxidation to iodine occurs, too).

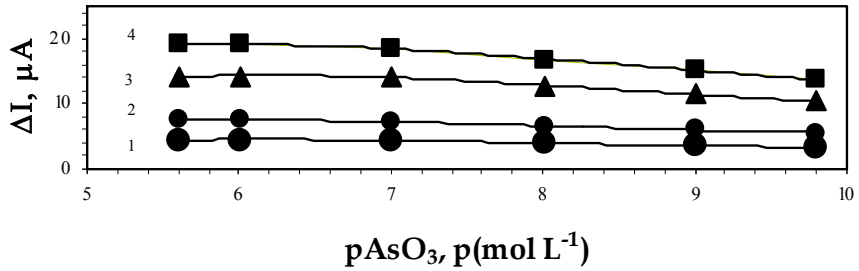

Fig. 2. Calibration curves for AsO_3^{3-} determination using different substrate concentrations: 1) 0.2 mmol L^{-1}; 2) 0.4 mmol L^{-1}; 3) 0.6 mmol L^{-1}; 4) 1 mmol L^{-1}; 5) 1.2 mmol L^{-1}. $pAsO_3$ is the negative decimal logarithm of the AsO_3^{3-} concentration.

As shown, the linear dynamic range of the calibration curves suitable for AsO_3^{3-} determinations varies from 0.2 nmol L^{-1} to 0.02 μmol L^{-1}. AsO_3^{3-} concentrations superior to 10 μmol L^{-1} caused an increase of the sensor response, due to the following concurrent reactions:

$$3I^- - 2e^- = I_3^-$$

$$H_3AsO_3 + I_3^- + H_2O = H_3AsO_4 + 3I + 2H^+$$

The sensitivity of the determinations, as shown in Table 2, increased with the increase of the acetylthiocholine iodide concentration until the enzyme saturation with 1.0 mmol L^{-1} acetylthiocholine iodide.

Substrate concentration, mmol L^{-1}	Sensitivity, μA/p(mol L^{-1})
0.2	0.39
0.4	0.65
0.6	1.25
1.0	1.65

Table 2. Sensitivity of As(III) determination

The method allows As(III) and As(V) differentiation, due to the fact that AsO_4^{3-} does not inhibit the acetylcholinesterase.

These preliminary results served for the development of a method for As(III) determination in wine. As known, arsenic content in some type of wines exceeds 0.1 mg L^{-1} (Crecelius, 1997). Arsenic concentration in contaminated illicit whiskey (moonshine) was found to be more than 0.4 mg L^{-1} (Gerhardt et al., 1980).

For the purposes of the analysis, commercially available wine was artificially contaminated with AsO_3^{3-} 0.0133 mmol L^{-1} (0.001 mg L^{-1}). The sample, without any pretreatment, was analysed according to the following protocol: (i) registration of the amperometric response of the electrochemical biosensor for a substrate concentration of 1.0 mmol L^{-1}, for which the sensitivity of the AsO_3^{3-} determination is maximal (25°C, Britton-Robinson buffer 0.1 mol L^{-1}, pH 7, 1000 rpm, +0.80 V/SCE) in the presence of no contaminated wine; (ii) registration of the amperometric response of the electrochemical biosensor in similar conditions, but in the presence of the contaminated wine sample; (iii) ΔI calculation and AsO_3^{3-} concentration

evaluation using a preliminary constructed calibration curve. The relative error of the analysis was found to be inferior to 3%.

6. Conclusion

The modern food analysis requires sensitive, accurate, and express methods for food safety, food quality, and food technology control. The growing field of the biosensors in food industry represents an answer to this demand. Thus, the method for As(III) determination in wine described in this work is an example demonstrating the viability of the electrochemical biosensors in food quality control.

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