Food additives in chemistry lessons

Els additius alimentaris a les classes de química

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abstract

Food additives are common food components and they should be studied in chemistry classes. This paper describes a lab lesson for high school seniors (17-18 years old). They tested some physical and chemical properties of four unknown additives. Using the test results the students had to figure out which four of the ten additives from a list given had been tested. The students worked in small groups. All four correct additives were chosen by 26 % of students (groups), three correct additives by 29 % and two correct additives by 45 % of students.

keywords
STS project, food additives, lab work.

resum

Els additius alimentaris són components comuns en els aliments i un bon context d'estudi per a les classes de química. En aquest treball, es descriu una sessió de laboratori per a estudiants de secundària (17-18 anys). Els alumnes van determinar algunes propietats físiques i químiques de quatre additius «desconeguts». Utilitzant els resultats de les proves, els estudiants havien d'esbrinar, entre els deu possibles additius d'una determinada llista, quins eren els quatre additius analitzats. Els estudiants van treballar en petits grups. Un 26 % dels estudiants (grups) va identificar correctament els quatre additius, un 29 % en va identificar tres i el 45 % en va identificar dos.

paraules clau
Projecte CTS, additius alimentaris, treball pràctic.

Introduction

A choice of content and teaching approach of a chemistry curriculum has been studied by methodologists for decades. A traditional approach (Fensham, 1985) selected topics important for chemistry science, making it (chemistry) self-serving choice. The STS (science–technology–society) project changed the traditional approach of science teaching (Aikenhead, 1994). Science education is viewed by the STS project from the point of how important science is in our society and how we can apply science in everyday life. There is a mutual relationship between science and society. The STS project does not view the reason for existence of scientific curriculums as only to serve required teaching plans and as a learning requirement for students (Yager, 1990).

The STS project considers mutual interactions between science, technology and society enabling inclusion of numerous topics. The concept of curriculums, teaching and learning methods about the macro-world should include the maximum number of examples from everyday life.

In Serbia, even current chemistry curriculums have teaching topics which could incorporate everyday life contents (referred to as *STS contents*). Some preliminary research exploring such contents has been performed. The following criteria for contents selection have been used:

– Up-to-date topics:

a) Health, related to healthy/unhealthy diet (intake of foodstuff, energy extraction from fuel molecules and energy consumption).

b) Food (manufacturing of food, food quality, world famine).

c) Contemporary diseases [causes and treatments: anorexia, bulimia, MS (metabolic syndrome), alcoholism, drug abuse, malignant diseases, etc.].

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d) Paradox chemicals (necessity vs. danger: food additives, metal ions, drugs, fuels, pesticides, alcohols, polymers).

– Ability to utilize knowledge acquired in past chemistry and other science courses and lessons during STS related lessons.

– Design of various types of student participation (group or individual) using various teaching methods (dialogs, textual methods, experiments).

– Availability of chemicals, glassware and other labware.

– Ability to organize lab activities for up to thirty students at a time.

Selected topics («Preservation and expiration date of foodstuffs», «Alcohol and young people alcoholism», «Metal ions in our body», «Antibiotics: chemistry view», «What chemists have to say about tobacco and smoking?», «Foodstuffs packaging», «Food additives») have been used in chemistry teaching since 1998-1999 school year in both middle and high schools. This preliminary research should serve as a foundation for introducing the STS principles in science teaching in Serbia (Korolija and Stanišić, 2009; Korolija *et al.*, 2008*a*; Korolija *et al.*, 2008*b*; Korolija *et al.*, 2009; Korolija *et al.*, 2012).

Food additives encompass a wide variety of organic and inorganic substances. A survey of teaching curriculums and plans for middle and high schools showed that food additives have been mentioned occasionally in classroom studies of certain chemical compounds. A common and traditional approach where students have passively accepted information from teachers and textbooks has been used in those cases.

Everybody should be aware of the presence of food additives in many foodstuffs and about adverse health effects caused by excessive use of additives. It is necessary, therefore, to teach basic properties, role and necessity of food additives in chemistry classes.

From the teaching method point of view, food additives are a very good material for creating practical problem-solving situations in teaching of and learning chemistry. Physical and chemical properties of food additives can be tested in simple ways in a school lab setting. Current preliminary research used such teaching situation for formative assessment of some acquired knowledge and skills of students.

What did the students do with food additives in the chemistry class?

Food additives were taught to high school seniors (17-18 years old). Those students already completed general, inorganic, organic and qualitative analytical chemistry courses and some biochemistry topics. Four periods were used to teach food additives. This paper describes in detail the lab portion which consisted of one 90 min session. The lab was preceded with a 45 min classroom session which included an introductory test, conversation and reading a text with some information on additives (appendix 1). After the lab, another 45 min classroom session was held in which the students were given a follow-up test (appendix 2) and a survey (appendix 3).

Eighteen and nineteen students (thirty-seven students total), respectively, participated in the two laboratory sessions. The students were divided in groups

Table 1. Groups of food additives given to students

Group of additives	*Food additive name*	*E number*
1	Sodium acetate	E262
	Tartaric acid	E334
	Mannitol	E421
	Potassium hydrogen sulfite (Vinobran)*	E228*
2	Sodium nitrite	E249
	Sodium nitrate	E251
	Boric acid	E284
	Sodium benzoate (Konzervans/Preservative)*	E211*
3	Sodium acetate	E262
	Tartaric acid	E334
	Manitol	E421
	Sodium hydrogen carbonate (Prasak za pecivo/Baking Soda)*	E500*
4	Sodium nitrite	E249
	Sodium nitrate	E251
	Boric acid	E284
	Citric acid (Limuntus)*	E330*

* signifies additives in original packaging with their commercial names in Serbian/and English translation, where appropriate; the E numbers for those additives were not given to the students.

of three (and one group of four) mixing them to get a balanced distribution based on their previous grades and performances. Every group was given four additives (out of ten selected for experiments). Every additive was given to at least two student groups. The food additive combinations by groups are given in the table 1.

What were the results of students' activities?

The standard student curriculum did not include a chapter on additives. Therefore, it was important to determine the students' baseline knowledge of additives. The correct individual student answers on the introductory test were 25-80 %, with an even distribution. The introductory test gave a good indication about the students' previous knowledge on additives. The lowest score for the follow-up test

Materials and products

– Test tubes and a rack, spoons, metal plate, beaker (for discarded solutions), paper towels.
– Additive samples (three of them in glass cups labeled with the corresponding E numbers, and the fourth in the original commercial packaging).
– 0.01 M hydrochloric acid and 0.01 M sodium hydroxide.
– Indicator solutions.
– Distilled water.

Table 2. The results obtained by testing four additives

Sample number	*Physical and chemical properties*					
	Organic	*Inorganic*	*Physical state*	*Color*	*Water solubility*	*Range of pH*

Experimental part

Every group of students received the materials and products that you can see above. They have to test given additives and to record the following properties in table 2, and then, based on experimental results, to propose one of ten list name for each of the four additives tested.

– Is an additive organic or inorganic? The students drew a conclusion after they heated the additive on a metal plate with a Bunsen burner (supervised by the teacher).
– Physical state.
– Color.
– Water solubility.
– Acidity (pH).

The students used indicators to determine acidities of additives. 0.01M hydrochloric acid and 0.01 M sodium hydroxide were provided for students. They recorded the results in the table 3.

Table 3. Testing colors of indicators in 0.01 M hydrochloric acid and 0.01 M sodium hydroxide

Indicator	*Color change range (pH)*	*Color*	
		In 0.01 M HCl	*In 0.01 M NaOH*
Litmus	5.0-8.0		
Methyl orange	3.1-4.0		
Bromthymol blue	6.0-7.6		

Table 4. List of additives

Chemical name	*Formula*
Tartaric acid	$HOOC\text{-}(CHOH)_2\text{-}COOH$
Potassium hydrogen sulfite	$KHSO_3$
Boric acid	H_3BO_3
Mannitol	$HOH_2C\text{-}(CHOH)_4\text{-}CH_2OH$
Sodium nitrate	$NaNO_3$
Sodium hydrogen carbonate	$NaHCO_3$
Citric acid	$\begin{array}{l} CH_2COOH \\ \vert \\ HOCCOOH \\ \vert \\ CH_2COOH \end{array}$
Potassium nitrite	KNO_2
Sodium benzoate	NaC_6H_5COO
Sodium acetate	$NaCH_3COO$

Table 5. Success rate of identifying additives by the groups of students

Groups	Additive									
	E334	E228	E421	E262	E284	E251	E249	E211	E500	E330
Total	4	2	4	4	4	4	4	2	2	2
Correct answers	4	2	2	2	2	3	3	2	2	2

was 30 %, and the highest, 90 %. All students scored better on the follow-up test than on the introductory test, but those results were not directly comparable since the tests were different. It should be noted, however, that almost 90 % of students scored over 60 % on the follow-up test.

As described previously, twelve groups of students were formed and four additives were given to each group. The total number of additives was ten. Every additive was given to at least two groups. Table 5 shows all groups of students successfully identified additives E334, E228, E211, E500 and E330. Four of those (five additives) were given to students in the original (commercial) packaging (table 1), which proved to be an important identification clue. In addition, all students collected sufficient data to identify tartaric acid, E334. It should be noted that every additive was identified by at least two groups.

If we analyze results from table 4 (second task), we can see that the number of correct answers was two to four. The majority of the groups had two correct answers (45 %), followed by three (29 %) and all four correct answers had 26 % of the groups.

The survey results show that generally all students were pleased to learn something important from everyday life. The opinion of the most of the students was that food should be included in chemistry curriculums. The survey answers show that there is a real need for such inclusion. Students need education to help them become educated consumers and be able to make good health choices.

Conclusion

General population does not have sufficient knowledge of additives which are unavoidable components of food. Many additives have harmful properties and are usually components of products primarily consumed by younger generations. Learning about food additives should be mandatory, not optional, in any educational system. Chemistry education, which teaches the science of matter, has the leading role in such learning. Through chemistry, students will learn and understand relationship between science, technology and society. Unfortunately, introduction of such innovative lessons is relatively slow and it is really up to teachers to introduce additives to their students.

We hope this paper will alleviate that process.

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Appendix 1. Some information about additives

An additive is a chemical compound which is not consumed as food, but added to food products during processing and/or manufacturing, to improve certain properties of foodstuffs. By a convention, every additive is assigned a specific E number, following the International Numbering System (INS).

By their origin, additives are classified as natural or synthetic, and by composition, as inorganic or organic. The functional (technological) classification in nine groups is the most important (seven groups of additives are listed here):

Colors (E100-E199)
Both natural and synthetic dyes are used for food coloring. Dyes are added when the technological food processing alters natural food color. Alternatively, food dyes are used to enhance visual appeal of foodstuffs. It is important that addition of dyes does not change other product properties. Dyes are used in bakery products, meat products, non-alcoholic beverages, ice creams, yogurts, soups, etc.

Preservatives (E200-E299)
Preservatives inhibit growth of microorganisms (bacteria, yeast and mold). They are used in practically all processed food (such as meats, fruit and vegetable products, sodas etc.). Nitrites (E250) are officially listed as poisons. However, they are still irreplaceable preservative for meat products preventing growth of *Clostridium botulinum*, which produces life threatening toxins. Nitrites toxicity can be kept under control when they are used in mixture with table salt (0.5-0.6 % nitrites).

Antioxidants & acidity regulators (E300-E399)
Antioxidants inhibit oxidation reactions and remove free radicals. They are used in almost all kinds of foodstuffs. In meat products they prevent oxidation of fatty acids. They also prevent darkening of peeled/cut fruits and vegetables. The well-known additives from this group are vitamin C (E300) and citric acid (E330).

Flavor enhancers (E600-E699)
As the name says they improve and enhance food flavor. They can be found in chips, meat products, chewing gums, soups, spreads, spices, mustard, etc. Best known additives from this group are glutamic acid and its salts. They activate certain receptors causing constant craving for products that contain them. Soy flakes are often added to foodstuffs. They easily ferment becoming acidic. Addition of monosodium glutamate (MSG, E621), neutralizes that acidity.

Sweeteners (E950-E969)
Diet products frequently use sweeteners which have low or zero calories, i. e. cannot be digested or participate in metabolic processes. They can be found in non-alcoholic beverages, candy, chewing gums, ice cream, sweets and drugs. There have been some reports that sweetener aspartame (E951) causes headaches, anxiety, perspiration and breathing problems. Experiments on rats showed that some symptoms of Parkinson's and Alzheimer's diseases can be caused by aspartame.

Appendix 2. Follow-up test

1. Explain the term *food additive*.
2. Explain what is the acceptable daily intake (ADI) of additives.
3. How are food additives classified by the composition?
4. Sodium salt of a non-essential amino acid is a food additive E621:
   a) Write the name and the molecular formula for that amino acid.
   b) How is this additive categorized by its functionality?
5. What is the reason for using sweeteners as sugar replacement? Name one sweetener.
6. Are the food containing additives recommended for children under the age of three and elderly population? Elaborate.
7. Explain how you determined if an additive was organic or inorganic in your experiments.
8. Complete the following sentences:
   a) Food additives are water _____.
   b) Bromthymol blue changes its color from _____ to _____ within the pH rang of _____. Addition of one drop of this indicator makes the aqueous solution of the additive E262 turn blue. The solution of E262 has the concentration of hydronium or hydroxyl ions of _____.
   c) Vitamin C, E _____ and citric acid, E _____ are additives from the group of _____.

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