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Analysis of food additives in selected food products and their potential impact on mental health

Analiza dodatków do żywności w wybranych produktach spożywczych i ich potencjalny wpływ na zdrowie psychiczne

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Abstract

Introduction: Food additives are commonly used to improve the taste, color, shelf life and texture of products. Although most of them are approved for use after safety assessments, there are still concerns regarding their impact on health, including mental functioning. The aim of this study was to qualitatively analyze the presence of selected chemical substances in chosen food products and to discuss the hypothetical mechanisms of their effects on mental health.

Material and methods: Fifteen food products were analyzed. The presence of chemical substances was determined using Fourier Transform Infrared Spectroscopy (FTIR), a technique that enables the identification of compounds based on their characteristic absorption spectra.

Results: The analysis revealed the presence of typical technological additives as well as trace chemical compounds, some of which may theoretically influence mental health, for example by altering perception, modulating glycemia or affecting memory and mood. FTIR was used as a screening method, which does not allow for definitive or quantitative identification of trace, atypical or controversial compounds. The obtained spectra may reflect both actual components and signals originating from the matrix, packaging, or library matching. Reports concerning some potentially harmful substances do not confirm their actual presence and require verification using confirmatory analytical methods.

Conclusions: The results should therefore be interpreted with caution and further research is necessary.

Keywords: Mental health, Mood disorders, Food additives, Chemical substances

Streszczenie

Wstęp: Dodatki do żywności są powszechnie stosowane w celu poprawy smaku, koloru, trwałości i konsystencji produktów. Choć większość z nich jest dopuszczona do użytku po ocenie bezpieczeństwa, wciąż istnieją wątpliwości dotyczące ich wpływu na zdrowie, w tym na funkcjonowanie psychiczne. Celem pracy była jakościowa analiza obecności wybranych substancji chemicznych w wybranych produktach spożywczych oraz omówienie hipotetycznych mechanizmów ich oddziaływania na zdrowie psychiczne.

Materiał i metody: Analizie poddano 15 produktów spożywczych. Obecność substancji chemicznych oznaczano metodą spektroskopii w podczerwieni z transformacją Fouriera (FTIR), która umożliwia identyfikację związków na podstawie ich charakterystycznych widm absorpcyjnych.

Dyskusja: Wykazano obecność typowych dodatków technologicznych oraz śladowych związków chemicznych, z których część może teoretycznie wpływać na zdrowie psychiczne, np. poprzez zaburzenia percepcji, modulację glikemii czy wpływ na pamięć i nastrój. FTIR zastosowano jako metodę przesiewową, która nie pozwala na pewną ani ilościową identyfikację śladowych, nietypowych czy kontrowersyjnych związków. Uzyskane widma mogą odzwierciedlać zarówno rzeczywiste składniki, jak i sygnały pochodzące z matrycy, opakowań czy bibliotecznych dopasowań. Doniesienia dotyczące niektórych potencjalnie niekorzystnych dla zdrowia substancji nie stanowią potwierdzenia ich realnej obecności i wymagają weryfikacji metodami potwierdzającymi. Wnioski należy interpretować ostrożnie; konieczne są dalsze badania.

Wnioski: Wyniki należy interpretować ostrożnie. Potrzebne są dalsze badania oceniające jakość produktów spożywczych na polskim rynku oraz wpływ dodatków chemicznych na stan zdrowia psychicznego.

Słowa kluczowe: Zdrowie psychiczne, Zaburzenia nastroju, Dodatki do żywności, Substancje chemiczne

Abstract

Food additives are commonly used to improve the taste, color, shelf life and texture of products. Although most of them are approved for use after safety assessments, there are still concerns regarding their impact on health, including mental functioning. The aim of this study was to qualitatively analyze the presence of selected chemical substances in chosen food products and to discuss the hypothetical mechanisms of their effects on mental health. Fifteen food products were analyzed. The presence of chemical substances was determined using Fourier Transform Infrared Spectroscopy (FTIR), a technique that enables the identification of compounds based on their characteristic absorption spectra. The analysis revealed the presence of typical technological additives as well as trace chemical compounds, some of which may theoretically influence mental health, for example by altering perception, modulating glycemia, or affecting memory and mood. FTIR was used as a screening method, which does not allow for definitive or quantitative identification of trace, atypical or controversial compounds. The obtained spectra may reflect both actual components and signals originating from the matrix, packaging or library matching. Reports concerning some potentially harmful substances do not confirm their actual presence and require verification using confirmatory analytical methods. The results should be interpreted with caution. Further studies are needed to evaluate the quality of food products on the Polish market and to assess the impact of food additives on mental health.

Key-words: *Food additives; Chemical substances; Mental health; Mood disorders*

1. Background

Food additives are widely used in food processing to improve the taste, color, shelf life, and texture of products [1]. They also include trace substances originating from materials used during production, packaging, transport, and storage [2]. In Europe, approximately 330 food additives are authorized, serving 27 technological functions. These additives are categorized as below:

- Colorants and pigments (E100–E199)
- Preservatives (E200–E299)
- Antioxidants and acidity regulators (E300–E399)
- Emulsifiers (E400–E499)
- Anti-caking agents (E500–E599)
- Flavor enhancers (E600–E699)
- Sweeteners (E900–E999)
- Modified starches (E1300–E1400)

Each food additive must undergo a health safety assessment. Only substances that have passed complete toxicological evaluations and are considered as safe are approved for use. Based on these assessments, an acceptable daily intake (ADI) is established [3]. In Poland, according to the Supreme Audit Office (NIK) guidelines, labels should include the percentage content of additives (indicated by the "E" number) and their contribution to the ADI. However, such information is often omitted [4]. When used within established limits, additives are not expected to adversely affect health [5]. Nevertheless, their long-term effects remain incompletely understood, raising concerns among consumers. Sensitive individuals may experience adverse reactions such as gastrointestinal discomfort (guar gum), headaches (monosodium glutamate), or skin reactions (xanthan gum, aspartame).

Food additives are present in thousands of products, including citric acid, modified starches, lecithins, sodium nitrite, carrageenan, monosodium glutamate, acesulfame K, and sucralose. Studies show that over 99% of artificially sweetened beverages, 95% of ice creams and 87% of industrial biscuits, cookies, and sandwiches contain at least one additive [6]. Choosing products with fewer additives and shorter shelf lives is recommended. Modern lifestyles favor the consumption of ultra-processed and fast foods. Additives are primarily used to extend shelf life, enhance sensory qualities and develop new types of foods, such as low-calorie or plant-based alternatives. The increased use of additives has prompted a research linking their consumption to various physical and mental health disturbances [7]. While generally considered safe at low concentrations, long-term molecular-level effects remain largely unexplored. The purpose of the study was to assess the presence of food additives in selected products and analyze their potential impact on consumer mental health.

2. Materials and Methods

2.1. Tested Samples

Food additives were assessed in 15 food products: (1) fruit caramels/candies; (2) blueberry jelly; (3) fruit dragees; (4) strawberry drink; (5) isotonic drink 1; (6) milkshake; (7) milk drink; (8) cola-type carbonated drink; (9) isotonic drink 2; (10) instant soup; (11) gummies; (12) strawberry curd in a tube; (13) powdered isotonic drink; (14) wafer dessert; (15) chewing candies. Solid samples were previously crushed, and a small portion was collected using a sterile spatula. Powdered products were also collected with a sterile spatula, while liquid samples were collected using a pipette.

2.2. Methods

Fourier Transform Infrared Spectroscopy (FTIR) is a chemical analysis method that enables the identification of chemical compounds and the determination of their structure based on the absorption of infrared (IR) radiation by the sample. During analysis, the sample is exposed to IR radiation, which is absorbed by chemical bonds characteristic of the molecule, such as stretching, bending, or twisting. The recorded IR spectrum, processed using Fourier transformation, allows for the detection of functional groups and bond types, and comparison with spectral databases enables the identification of specific compounds [8]. In fact, FTIR is widely used in the analysis of food colorants and additives, quality control, contamination detection, as well as in pharmaceutical, cosmetic, and polymer material studies. The method is fast, non-invasive, and requires only a small sample amount, making it particularly convenient for analytical laboratories [8].

FTIR spectroscopy in ATR mode was used to analyze the examined material. Transmittance spectra (T) were recorded, defined as the ratio of the intensity of radiation transmitted through the sample to the intensity of the incident radiation. Absorbance (A) was calculated according to the relation $A = \log_{10}(1/T)$. The FTIR-ATR spectra were recorded using a Thermo Fisher Scientific Nicolet spectrometer equipped with an iD5 ATR accessory with a diamond window. Measurements were carried out in the range of 4000–525 cm^{-1}, with 32 scans and a resolution of 4 cm^{-1}. A DTGS/KBr detector was used, and the beam splitter was made of KBr. The obtained spectra were analyzed using a reference spectral library and characteristic vibrational bands, and the interpretation was performed using the OMNIC software.

3. Results

Figure 1 presents the FTIR analysis of one of the tested samples. Table 1 shows the compounds detected in the individual samples. Based on the analysis, it was found that candies and gummies are dominated by sugar compounds (sucrose, dextrose, mannitol) and alcohols (methyl alcohol, limonene). Some of them also contain aldehydes and aromatic substances. In beverages, more complex chemical compounds were potentially present, including LSD tartrate, formaldehyde, butyramide, opium powder, methylamine, and various amino acids and salts.

*Table 1. Identified chemical compounds**

Sample Number	Detected Chemical Compounds
1	Mannitol (mannitol, E421), Sucrose (sucrose, E955), Phenylphosphonic acid, Benzyl alcohol, (R)-(+)-Limonene, (R)-(-)-1,3-Butanediol, (S)-(+)-1,3-Butanediol, 1,3-Difluoro-2-propanol, Ascorbic acid (vitamin C, E300)
2	Sucrose (sucrose, E955), 1,6-Heptadien-4-ol, 1-Hexene, (R)-(-)-1,3-Butanediol, (S)-(+)-1,3-Butanediol, Methyl alcohol, cis-8,cis-10-Dodecadienol, Mannitol (mannitol, E421), (R)-(+)-Limonene
3	Sucrose (sucrose, E955), 1,6-Heptadien-4-ol, Methyl alcohol, 1-Hexene, (R)-(-)-1,3-Butanediol, (S)-(+)-1,3-Butanediol, cis-8,cis-10-Dodecadienol, Mannitol (mannitol, E421), (R)-(+)-Limonene
4	N-(2-Ethoxyphenyl)-N-(2-ethylphenyl)-ethanediamide, Formaldehyde, Butyramide, Opium powder, LSD tartrate, D-Pantothenyl alcohol, Dimethylamine, Lactose powder (lactose, E966), Streptomycin sulfate, Lysergic acid diethylamide (LSD)
5	N-(2-Ethoxyphenyl)-N-(2-ethylphenyl)-ethanediamide, Butyramide, Formaldehyde, Opium powder, LSD tartrate, Dimethylamine, D-Pantothenyl alcohol, Lysergic acid diethylamide (LSD), Lactose powder (lactose, E966)
6	N-(2-Ethoxyphenyl)-N-(2-ethylphenyl)-ethanediamide, Formaldehyde, Butyramide, Opium powder, D-Pantothenyl alcohol, LSD tartrate, Tungstic acid, Streptomycin sulfate, Lactose powder (lactose, E966), Polyarylamide
7	Formaldehyde, Butyramide, N-(2-Ethoxyphenyl)-N-(2-ethylphenyl)-ethanediamide, Opium powder, D-Pantothenyl alcohol, LSD tartrate, Streptomycin sulfate, Lysergic acid diethylamide (LSD), Tungstic acid, Antipain dihydrochloride

8	N-(2-Ethoxyphenyl)-N-(2-ethylphenyl)-ethanediamide, Formaldehyde, Opium powder, Butyramide, LSD tartrate, D-Pantothenyl alcohol, Lactose powder (lactose, E966), Dimethylamine, Lysergic acid diethylamide (LSD), Streptomycin sulfate
9	N-(2-Ethoxyphenyl)-N-(2-ethylphenyl)-ethanediamide, Opium powder, Formaldehyde, Butyramide, LSD tartrate, Lactose powder (lactose, E966), D-Pantothenyl alcohol, Dimethylamine, Lysergic acid diethylamide (LSD), Triton W-30
10	Polycarbonic acid carbonate, Polyethylene mix, Mono and diglycerides (E471), Emuldan HV52, Diglycerides, Poly(vinyl stearate), Poly(ethylene:propylene:diene), Monoelaidin, Alkyd resin, Triacontane, Ethoxylated stearyl amine
11	Cellophane, Methyl-13C alcohol, Allyl alcohol, Formaldehyde, Dextrose anhydrous (E1400), Dextrose monohydrate, Isomaltose, cis-8,cis-10-Dodecadienol, Sucrose (sucrose, E955)
12	Formaldehyde, N-(2-Ethoxyphenyl)-N-(2-ethylphenyl)-ethanediamide, Butyramide, Opium powder, D-Pantothenyl alcohol, LSD tartrate, Streptomycin sulfate, Tungstic acid, Lactose powder (lactose, E966), Chondroitin sulfate
13	Chloroform, Iopanoic acid, Isophorone, Lorazepam, m-Carboxybenzotrifluoride, 2,5-Dimethylpyrrole, Bromodichloromethane, Poly(vinylidene fluoride:C3F6), Methyl adipate, Dextrose monohydrate
14	Methyl-13C alcohol, Cellophane, Dextrose monohydrate, Sodium thiosulfate (E539), Dextrose anhydrous, Isomaltose, Allyl alcohol, Trans-piperylene, Mannitol (mannitol, E421)
15	Sucrose (sucrose, E955), Cellophane, cis-8,cis-10-Dodecadienol, Dextrose anhydrous, 1,6-Heptadien-4-ol, 1-Hexene, Dextrose monohydrate, Isomaltose, Methyl alcohol

These compounds were suggested to be present in the analyzed samples and may have adverse effects on mental health.. Sugar compounds (sucrose, dextrose, mannitol) and sugar alcohols may indirectly affect mood and concentration, whereas aromatic substances and certain alcohols may exacerbate stress responses in sensitive individuals. Polymers and non-digestible substances have minimal impact, primarily limited to digestive discomfort, which may indirectly influence one's well-being. The potential effects of individual chemical compounds on mental health are presented in Table 2.

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*Table 2. Estimation of the potential impact on mental health resulting from the hypothetical presence of the analyzed compounds in the samples**

Chemical Compound	Number of Samples	Potential Impact on Mental Health
Sucrose (E955)	7	Glucose fluctuations, possible irritability, decreased concentration, mood deterioration
Mannitol (E421)	5	Glucose fluctuations, possible irritability, decreased concentration, mood deterioration, gastrointestinal symptoms
Glucose (Dextrose, anhydrous or monohydrate)	5	Glucose fluctuations, possible irritability, decreased concentration, mood deterioration, gastrointestinal symptoms
Lactose powder (E966)	7	Bloating, gastrointestinal symptoms, indirect effect on mood
Limonene (R-(+)-Limonene)	4	May have relaxing effects and improve mood (aromatherapy)
1,3-Butanediol	3	Limited data – potential neuroactive effect
1,6-Heptadien-4-ol	4	Limited data – possible stimulating or irritating effect
cis-8,cis-10-Dodecadienol	4	No data available regarding impact on mental health
Formaldehyde	8	Neurotoxic effects, headaches, fatigue, concentration problems
Butyramide	7	Limited data – potential neurotoxic effect with long-term exposure
N-(2-Ethoxyphenyl)-N-(2-ethylphenyl)-ethanediamide	7	Limited data – potential neuroactive effects

**The presence of the analyzed compounds must be confirmed by appropriate reference methods.*

4. Discussion

Chemical analyses of various food products revealed the presence of numerous substances that may serve technological functions, such as stabilization, flavoring, coloring, or texture modification. The analysis of chemical compounds in the tested samples shows clear differences between product groups. In candies and powdered isotonic drinks, compounds typical for these products were detected, including ascorbic acid, used as a color stabilizer and antioxidant [9]. Natural colorants enhance the product appearance and may be associated with fruit flavors [10]. The presence of cellophane suggests potential contamination during the manufacturing process [11]. In jelly products, the synthetic dye indigo carmine was used to ensure stable coloring, although it is less durable than natural dyes [12]. Natural colorants in wafer decorations, such as carmine and betanin, are generally considered safe, though carmine may trigger allergic reactions in a small percentage of individuals [13]. Other studies suggest that Brown HT and Brilliant Black PN may exhibit potential toxic and genotoxic effects [14].

The presence of streptomycin in food products, according to current scientific evidence, poses a risk to consumer health, including the potential development of antibiotic-resistant bacteria, disruption of the gut microbiome, and allergic or toxic reactions in sensitive individuals [15]. Therefore, the detection of this compound indicates the need for strict production control and adherence to withdrawal periods. In beverages and dairy products, LSD and opium alkaloids were potentially detected. The analysis of FTIR enables the identification of characteristic functional groups of these substances, which may be present even in trace amounts; however, these reports require confirmation by validated methods [16]. Colorants in beverages play a crucial role in taste perception and product appeal [17]. Some synthetic dyes, such as tartrazine, may trigger allergic reactions in sensitive individuals, and ammonium-sulfite caramel present in carbonated beverages may contain 4-methylimidazole, which has potential toxic effects [9].

Knowledge regarding the impact of many artificial, especially synthetic, food additives on mental health remains limited. These additives may induce changes in the host gut microbiome, with different substances exerting varying effects on the same microbial taxa [18]. Consequently, it is difficult to predict the cumulative effects of multiple additives. Food additives may also trigger immune responses, leading to antibody production and the release of inflammatory mediators. These reactions can manifest as dermatological or respiratory symptoms, and in severe cases, they may be of a systemic nature. Chronic inflammation can affect central nervous system function, as pro-inflammatory cytokines modulate neurotransmission and emotional regulation

[19]. Prolonged inflammation may also compromise the intestinal barrier integrity, increasing gut permeability to toxins and microorganisms, thereby further disrupting the gut–brain axis [20].

The obtained results should be interpreted with caution, taking into account the limitations of the applied method. Although FTIR is useful as a screening tool, it remains a qualitative technique and does not allow for unambiguous quantitative identification of food additives. Therefore, it cannot serve as an independent basis for drawing definitive conclusions. In particular, for compounds reported as present in trace amounts and raising safety concerns, results require confirmation. The presence of these compounds could be verified using quantitative methods with higher sensitivity and selectivity, such as chromatographic techniques. The use of such tools would allow for unambiguous identification and reliable assessment of the concentrations of potentially present compounds. The combination of FTIR with other multidimensional methods enables the detection of adulterants in food samples at very low concentrations. The method has demonstrated the ability to identify melamine and cyanuric acid in powdered infant milk mixtures at concentrations as low as 0.0001% [26]. The sensitivity and accuracy of FTIR can be significantly enhanced through integration with chemometric models, such as partial least squares regression (PLSR) and discrete wavelet transform (DWT-PLS) [27]. These models aid in the extraction of weak absorption signals and improve prediction accuracy. Individual studies suggest that FTIR may be applied as a standalone method; however, this requires extensive method validation, including assessments of repeatability, precision, sensitivity, specificity, and standardization of measurement procedures [27–29].

Conclusions

1. The analyses indicated the potential presence of numerous technological additives in food products, varying across product groups (sweets, beverages, jellies, dairy products). However, these findings require confirmation using reference methods and additional studies on a larger sample.
2. The detected presence of potentially harmful substances in food may result from spectral matching artifacts, complex sample matrices, contamination (e.g., from packaging), or data processing procedures.
3. Certain synthetic compounds and antibiotic residues may pose health risks, including toxic, allergic, or genotoxic effects, necessitating strict control of production processes.
4. Food additives may influence the functioning of the nervous system and gut microbiome, indirectly affecting mental health, mood, and allergic responses.
5. Further research is needed to evaluate the quality of food products on the Polish market and the impact of chemical additives on mental health.

Conflict of interest

The authors have declared no conflict of interest.

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