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FACULTY OF FOOD ENGINEERING, TOURISM AND ENVIRONMENTAL PROTECTION

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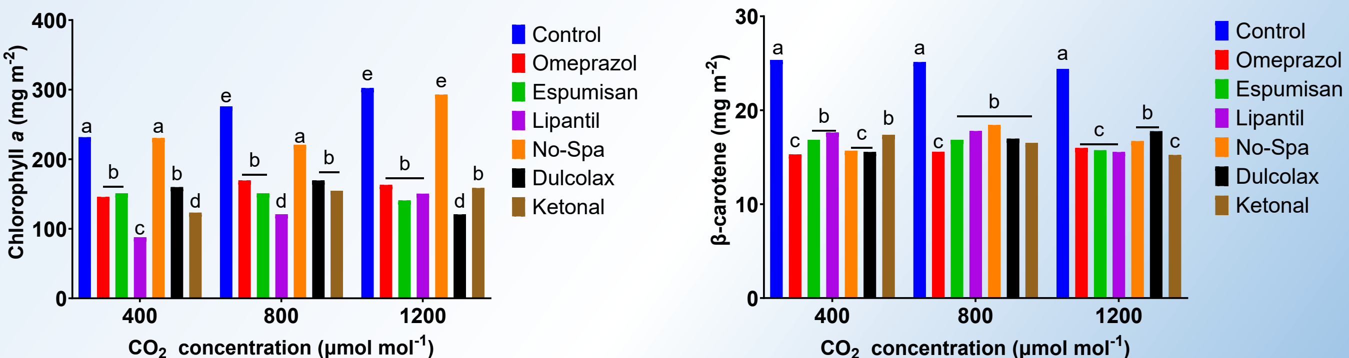
THE INFLUENCE OF EXPIRED MEDICINES ON PLANT PHOTOSYNTHESIS PARAMETERS AND CHLOROPHYLL PIGMENTS,

Lucian COPOLOVICI, Flavia BORTES, Brenda SVINTI, Andreea LUPITU, Cristian MOISA, Dana COPOLOVICI (Pages 18-24)



The influence of drugs on chlorophyll pigments in the leaves of plants grown at various CO_2 concentrations.

Year XXI, Vol. 20, 2023

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ADDRESS

Faculty of Food Engineering, Tourism and Evironmental Protection,
„Aurel Vlaicu” University of Arad, Elena Dragoi St., Nr. 2, L31, Arad, Romania
Phone: 0040257369091
E-mail: dana.copolovici@uav.ro

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Review

WAYS TO DETERMINE COLIFORM BACTERIA IN FOOD – A MINI REVIEW

Ionel POPESCU-MITROI[1]

[1]*Faculty of Food Engineering, Tourism and Environmental Protection, "Aurel Vlaicu" University, Romania, 2 Elena Drăgoi, Arad 310330, Romania*
Corresponding author email: ionel89@hotmail.com

Abstract: *The presence/absence of coliform bacteria in food is a hygienic-sanitary indicator that provides valuable information about the hygienic conditions in which the food was processed. The determination of coliform bacteria in food using the classical method (multiple-tube method) is a laborious work, and the results take a long time. In recent years, modern techniques for the determination of coliform bacteria have emerged, which include enzyme tests, ELISA techniques, PCR techniques, and spectrophotometric techniques, with much faster results.*
In this paper, the use of ion mobility spectrometry for the determination of o-nitrophenol (ONP), a volatile marker generated by the E. coli species, is briefly described, discussing both the strengths and weaknesses of this method.

Keywords: coliform bacteria, classic and modern methods, ONP, food.

INTRODUCTION

Coliform bacteria are part of the *Enterobacteriaceae* family, and include the genera *Escherichia*, *Klebsiella*, *Enterobacter*, and *Citrobacter*.

Coliform bacteria are considered indicators of food safety, and are used to estimate the degree of hygiene and microbial innocuousness of food processing.

Physiologically and depending on the source, coliforms can be:

- faecal coliforms (FC) characterised by rapid growth in 16 hours, in a nutrient broth medium at 41-44°C (these are considered hygienic indicators that highlight the contamination of food with faecal matter)
- non-faecal coliforms (NFC) of aquatic or telluric origin multiply at 4°C in 2-4 days, are unable to grow at 41°C, being psychrotrophs (Dan, 1999).

In the past, the genus *Escherichia* was thought to have only one species, *E. coli*. Taxonomic research has shown that the genus *Escherichia* comprises 5 species: *E. coli*, *E. blattae*, *E. fergusoni*, *E. hermani*, and *E. vulneris* (Bârzoi&Apostu, 2002). *E. coli* represents the type species of the genus, is a Gram-negative, aerobic/facultative anaerobic, non-sporogenous, acapsulogenic, and motile coccobacillus. *E. coli* is an indicator of faecal pollution (it is eliminated in the same way as the pathogenic bacteria present in sick individuals), and it can develop in water and food. *E. coli* is sensitive to common disinfectant substances at the usual concentrations in current practice, which is why this bacterium is the main indicator for checking the efficiency of the sanitisation and disinfection operation in the food industry and public catering (Șerban&Călugăru, 2005).

Currently, *E. coli* serotypes can be classified into 4 main groups (Doyle&Padhye, 1989; Milon, 1993):

- group I enteropathogenic *E. coli* (EPEC) strains
- group II enterotoxigenic *E. coli* (ETEC) strains
- group III enteroinvasive *E. coli* (EIEC) strains
- group IV enterohemorrhagic *E. coli* (EHEC) strains

Food poisoning outbreaks have been particularly associated with VTEC (verotoxin) and, to a lesser extent, EPEC, ETEC and EHEC strains (Ramos *et al*., 2020; Basak & Ahmet, 2017). Determining EPEC, ETEC and EIEC in food faces some difficulties due to the associated microflora. For this reason, the use of selective enrichment and isolation media is required.

The classic method for determining coliform bacteria includes presumptive tests, confirmatory tests, and biochemical tests based on the ability of coliform bacteria to ferment lactose (similar to lactic acid bacteria) at 35-

37°C for 48 hours, and to produce lactic acid, carbon dioxide, and hydrogen. The classic technique for determining coliform bacteria has the disadvantage of being laborious, with the final results known only after 5-6 days. Modern techniques for determining coliform bacteria are more demanding in terms of equipment, are less laborious, and the results are much faster.

CLASSIC METHOD

In the classic technique for the determination of coliform bacteria (multiple-tube method), lactose broth is used as enrichment media, and BGBL (Brilliant Green Bile Lactose) or Lauryl Sulphate Broth as liquid confirmatory media (Dan *et al.*, 1991; Oprean, 2002). Mac Conkey agar (VRBL - Violet Red Bile Agar with Lactose), Levine EBM medium (Eosin Methylene Blue Agar), or Rambach medium is used as solid identification media (Manafi, 2000).

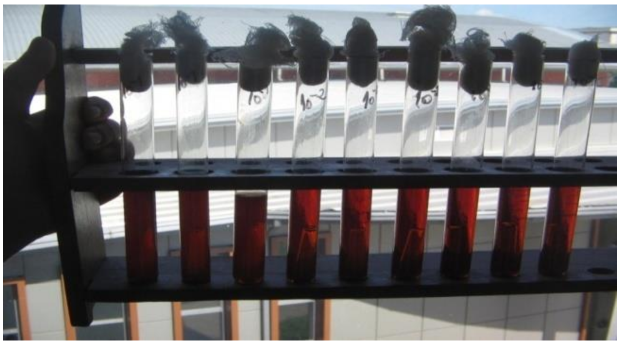

Figure 1. Durham tubes with BGBL medium for the determination of coliform bacteria in milk (personal archive photo)

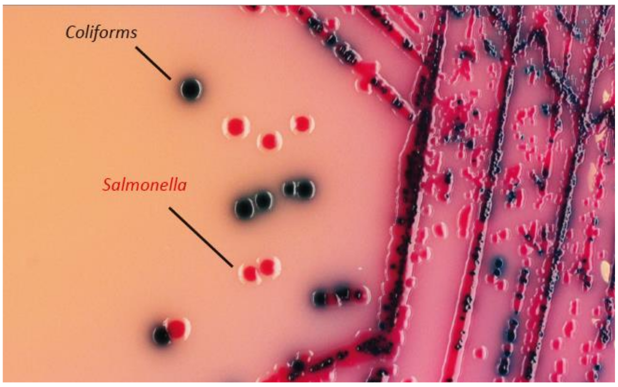

Figure 2. Differentiation of coliform colonies on Rambach medium (Rambach catalogue – instructions for use)

After confirmation, the formula used for the biochemical differentiation of *E. coli* from *Enterobacter aerogenes* is the IMVC formula described in Table 1:

Table 1. Biochemical differentiation of the *E. coli* species (Dan *et al.*, 1991)

Species	I	M	V	C	Mobility
Escherichia coli	+	+	-	-	+
Enterobacter aerogenes	-	-	+	+	-

I – production of indole from tryptophan
M – reaction with methyl red
V – the Voges Proskauer reaction for the production of acetoin
C – the use of citrate

MODERN METHODS

Most of the modern determination techniques of the coliform bacteria include enzyme tests (determination of β-galactosidase as the main metabolite), ELISA techniques (determination of verotoxins), PCR techniques, spectrophotometric techniques, (Bouvet&Vernozy-Rozand, 2000; Bellin *et al.*, 2001). Another modern techniques use a microbial photoelectric detection system which quantifies microorganisms by detecting the light signal generated by the measured sample during growth (Cui *et al.*, 2023).

In immunoenzymatic analysis methods, different marker enzymes can be used depending on the metabolite to be dosed. Table 2 lists the enzymes most commonly used as markers together with the main chromogens and the wavelengths at which maximum absorbance is measured.

Table 2. Main marker enzymes used in immunoenzymatic techniques (Cojocaru *et al.*, 2007)

Marker enzyme	Chromogenic substrate	Product and wavelength corresponding to maximum absorbance
Peroxidase	o-phenylenediamine	o-nitroaniline (λ = 492 nm)
Alkaline phosphatase	p-nitrophenyl phosphate	p-nitrophenol ((λ = 405 nm)
β-D-galactosidase	o-nitrophenyl-β-D-galactopyranose	o-nitrophenol (λ = 405 nm)
β-D-galactosidase	4-methyl-umbelliferyl-β-D-galactopyranose	4-methyl-umbelliferone with fluorescent properties ($\lambda_{emission}$ = 448 nm)
Glucose oxidase	o-phenylenediamine	o-nitroaniline (λ = 492 nm)
Glucose-6-phosphate dehydrogenase	glucose-6-phosphate	$NADPH+H^+$ (λ = 340 nm)

Table 2 shows that marker enzyme β-D-galactosidase can be determined using two methods, both by measuring the absorbance, and by measuring the emission of the product resulting from the reaction.

One of the modern methods for determining coliform bacteria is based on the reaction of the extracellular enzyme β-galactosidase with o-nitrophenyl β-D-galactopyranose (ONPG). The enzyme cleaves the substrate generating a colourless saccharide (galactopyranose) and o-nitrophenol (yellow ONP compound); this coloured compound is detected spectrophotometrically at wavelengths λ = 405 nm (Rațiu *et al.*, 2017)

In a series of works (Bocoș-Bințințan, 2004; Peter-Snyder *et al.*, 1991a; Strachan *et al.*, 1995; Peter-Snyder *et al.*, 1991b), the use of ion mobility spectrometry was described to investigate the bacterial enzyme/substrate reaction by investigating the analyte produced in an unconventional manner. Thus, the property of ONP to have a relatively high vapour pressure (0.54 torr at 40°C) is used, which allows the direct analysis of these vapours using ion mobility spectrometry (IMS).

ONP is a universal volatile marker for several bacterial species as shown in Table 3:

Table 3. Markers generated by various bacterial species (Strachan *et al.*, 1995)

Microorganisms	Substrate used	Generated volatile marker
E. coli	o-nitrophenyl β-D-galactopyranose (ONPG)	ONP
Yersinia	Urea	Ammonia
Aeromonas	o-nitrophenyl β-D-galactopyranose (ONPG)	ONP
Listeria	o-nitrophenyl β-D-glucopyranose (ONPGluco)	ONP
Staphylococcus aureus	o-nitrophenyl β-D-galactoside-6-phosphate	ONP

In their research, Snyder et al. used a CAM (Chemical Agent Monitor) ion mobility spectrometer (IMS) operated in negative mode (negative ions produced by ONP were detected). *E. coli* suspensions were prepared by growing in a nutrient solution for 48 hours to which 0.5% lactose was added to induce the β-galactosidase enzyme; the ONPG solution had a concentration of 2 mg/mL in sterile pH 7.4 phosphate buffer solution. The procedure was as follows: 2 µL of the ONPG solution and 2 µL of the *E. coli* suspension in phosphate buffer were added to a 15 mm diameter sterile filter paper disc. After a short incubation period at 40-42°C, the headspace atmosphere in the glass vial containing the filter paper disc was sampled using the IMS apparatus (Peter-Snyder *et al.*, 1991a).

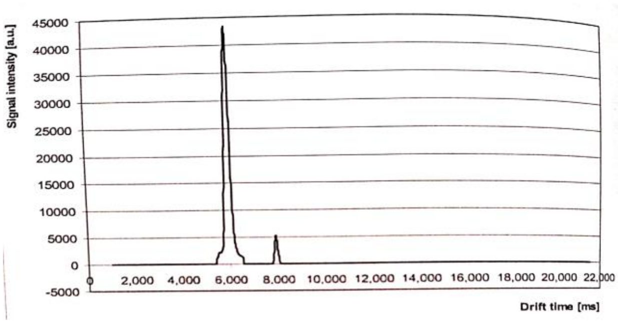

Figure 3. The ion mobility spectrum of ONP following the development of coliform bacteria at a temperature of 42°C (Bocoș-Bințințan&Rațiu, 2009)

The ion mobility spectrum shown in Figure 3 shows two distinct peaks: the 5.96 millisecond RIP peak, and the 7.92 millisecond peak generated by ONP (the target analyte), of much lower intensity.

CONCLUSIONS

The determination of coliform bacteria in water and food by ion mobility has both advantages, and disadvantages. Among the advantages we have identified:

- determination takes place in real time (drift times are a few milliseconds)
- the sensitivity is extremely high (the ONP analyte is detected to the order of parts per billion-ppb, or even parts per trillion-ppt)
- the device is portable, the cost of the instrument is quite low.

Among the disadvantages we identified:

- ONP is a volatile marker that is also generated by other types of bacteria, other than coliform bacteria (g. *Aeromonas*, g. *Listeria*, g. *Staphylococcus*)
- the linear range of response in ion mobility spectrometry (IMS) is limited, having negative consequences on the

quantitative determinations of the analyte (ONP), and implicitly on the determination of coliform bacteria.

In conclusion, the ion mobility spectrometry technique lends itself to the determination of coliform bacteria in food when their number is low and there are no other ONP-generating microorganisms in the product that would affect the result.

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Article

THE IMPORTANCE OF TEXTILE RECYCLING FOR FAST-FASHION CONSCIOUS PEOPLE

Andreea RĂCEU[1], Mălina Paula TEGLAȘ[2], Delia GLIGOR[1*]

[1] *Faculty of Environmental Science and Engineering, Babeş-Bolyai University, 30 Fantanele Street, RO-400294, Cluj-Napoca, Romania*
[2] *Faculty of Industrial Engineering, Robotics and Production Management, Technical University of Cluj-Napoca, 400641 Cluj-Napoca, Romania*
[*] *Corresponding author email: delia.gligor@ubbcluj.ro*

***Abstract**: The textile industry's pollution is a growing environmental concern. This study promotes sustainable fashion awareness through clothing recycling. By addressing strengths, weaknesses, opportunities, and threats, we aim to advance eco-friendly fashion. This research can benefit future students and interested individuals. Our methodology included a questionnaire with 105 respondents. Results revealed high support for clothing recycling. The study emphasizes textile waste's environmental consequences, such as water and energy consumption, greenhouse gas emissions, and ecosystem pollution. While most people are environmentally concerned, apathy still poses a threat to the environment.*

Keywords: textile recycling, fast-fashion, sustainable development.

INTRODUCTION

Textile products, especially clothing, are part of the primary human needs, and the development of human society is obviously reflected in their diversity, quality and ability to better satisfy the needs of society members (Udrea, 1990). The quick development of the world economy in recent decades has confronted contemporary society with new problems, among which an important place is occupied by the use, to an ever-greater extent, of materials from non-renewable sources (Florescu, 1985). The materials used in the textile industry can be classified into two main categories: natural textiles and synthetic textiles. This distinction is based on the raw material used and the manufacturing process.

Natural textiles are made from fibers with natural origins, such as animal fur and skin, plant seeds, leaves and even certain minerals. These represent the oldest resources for textile production and include well-known materials such as cotton, wool, silk, linen, hemp and cashmere.

On the other hand, synthetic textiles are obtained by synthesizing fibers with the help of technology, using chemicals such as petroleum and coal (Florescu, 1985). Synthetic fibers require less manual labor and can benefit from mechanized and automated manufacturing processes, resulting in lower costs and a wider range of applications with lower initial investment. Notable examples in this category include polyester, acrylic, nylon, rayon, acetate, spandex, latex, and kevlar.

The waste generated by the textile industry can be divided into five main categories. There are pre-consumer wastes which are yarn and fabric scraps resulting from the manufacturing process (Nayab-Ul-Hossain et al., 2023) or waste generated from product packaging, such as cardboard, plastic film and labels (Sareen et al., 2018). Post-consumer waste originating from discarded textiles such as clothing, household products (e.g., bed linen, towels, curtains) and non-reusable textiles such as upholstery and carpets (Sareen et al., 2018).

Process waste consists of water contaminated with dyes and chemicals resulting from textile dyeing and printing, chemical waste generated from the use of chemicals and solvents, as well as carbon and other emissions with a negative impact on the environment, generated by energy consumption in the processes of manufacturing (Sareen et al., 2018). By-products and recyclable waste - cotton waste, fabric scraps and textile strips that can be reused, residual thread waste from weaving or sewing processes, and paper waste from administrative activities and packaging (Nayab-Ul-Hossain et al., 2023; Sareen et al., 2018), hazardous waste - chemical contaminants, such as dyes, bleaches and finishing agents, which can contaminate wastewater and pose risks to the environment and human health in the absence of proper management. Also, agricultural practices associated with textile fiber production can generate hazardous waste in the form of pesticides and biocides, which have a negative impact on the environment and natural resources (Sareen et al., 2018). To minimize the impact on the environment, each of these categories is managed, collected, stored and treated separately.

Textile waste has a significant impact on the environment, including landfill overcrowding, water pollution with harmful chemicals, excessive consumption of energy and natural resources, greenhouse gas emissions and microplastic pollution. Landfill overcrowding is caused by the fact that textiles, especially synthetic ones, decompose very slowly, taking up valuable space and emitting greenhouse gases during decomposition (Weber, 2015). Water pollution occurs due to chemicals used in the textile process (Aishwariya, 2018), affecting aquatic ecosystems (Saravanja et al. 2022). Also, the textile industry requires substantial amounts of resources and energy, contributing to their depletion and climate change (Weber, 2015; Martire, 2021).

Greenhouse gas emissions are linked to the entire life cycle of textiles, from manufacturing to disposal, contributing to global warming (Martire, 2021). Microplastic pollution is a growing problem, especially from synthetic textiles, which release microplastics into the environment during washing. These plastic particles end up in the oceans and affect marine life, also threatening human health through the food chain (Saravanja et al. 2022; Katsnelson, 2015). In addition, textile production can lead to biodiversity loss through deforestation and the conversion of natural habitats to agricultural land or plantations. All these harmful effects highlight the importance of managing and reducing the impact of the textile industry on the environment (Martire, 2021).

This paper is based on research to provide a simple and comprehensive theoretical framework regarding people's perspective on the importance of recycling clothing items. Pollution caused by the textile industry has become a major environmental problem in recent decades. Overall, this paper aims to contribute to the knowledge of the concept of sustainable fashion by making people aware of the importance of recycling clothing items. By highlighting strengths, addressing weaknesses, capitalizing on opportunities, and managing threats, we can pave the way for a more sustainable and environmentally responsible fashion industry.

The term "fast fashion" is based on the rapid and mass production of clothing items, following current fashion trends and emphasizing low costs and quick availability for consumers. Collections are created and manufactured at an accelerated pace, often at affordable prices, to meet consumer demand as quickly as possible.

The economic impact of "fast fashion" lies in stimulating consumption by promoting new trends and collections at short intervals, leading to increased sales and profits for fashion brands. However, this model can also contribute to reducing production costs, including through the use of cheap labor and the exploitation of natural resources in developing countries.

From a social perspective, "fast fashion" can have negative consequences on working conditions and the rights of workers in the textile industry, especially in countries where the production process takes place. Additionally, promoting a culture of excessive consumption can lead to increased waste and constant pressure on natural resources.

The environmental impact is significant, as "fast fashion" contributes to generating large amounts of textile waste, water and soil pollution, and greenhouse gas emissions. Moreover, the use of toxic chemicals in the production process can severely affect the environment and human health.

Thus, fast fashion is associated with immediate economic benefits but generates significant negative impacts on society and the environment. Therefore, a more responsible and sustainable approach is necessary in the fashion industry.

The aim of this study is to provide a realistic vision of textile recycling management.

The research subject can be placed in a broader context of sustainable development policies, in line with the 2030 Agenda for

Sustainable Development adopted by the member states of the United Nations. Specifically, it can be associated with Sustainable Development Goal 12, which aims to ensure responsible consumption and production. By promoting awareness and practices of sustainable fashion, including clothing recycling, our research contributes to achieving this global objective. Thus, by reducing textile waste and promoting a more responsible consumption pattern, we align with global efforts for sustainable economic and social development.

The objective developed in this paper is to obtain a large volume of people's opinions on textile recycling and analyze them in detail. It is extremely important to maintain a balance between quality, time, performance and costs, four extremely important dimensions to follow throughout the preparation of the material. (Olt, Szasz, 2019)

The hypotheses on which the research is based are:

– There is an increasing public awareness regarding environmental issues.
– The demand for sustainable and recycled products is on the rise.
– The fast-fashion industry dominates the market, generating a significant amount of textile waste.
– Consumers may not be sufficiently aware of the importance of textile recycling.
– Recycling technologies need to continue to develop and improve.
– Textile recycling infrastructure may be underdeveloped in some regions.
– The costs of recycling technologies can be high.
– Government regulations concerning the environment and recycling may be constantly changing.

MATERIALS AND METHODS

Methodology

As for the methodology, specialized literature was consulted, and it was determined that employing a questionnaire would likely be the optimal approach for collecting diverse perspectives and maximizing the amount of gathered data.

The questionnaire was distributed online through the Google Forms platform. The link to the form was disseminated across various online channels, such as social media networks, relevant discussion groups, and by directly sending the link to potential respondents via email or other online communication means. The distribution of the questionnaire took place over a specified period of time (one week in March 2023) to allow for the collection of a sufficient number of responses and to ensure the representativeness of the sample. All respondents are from Romania.

(i) Study participants

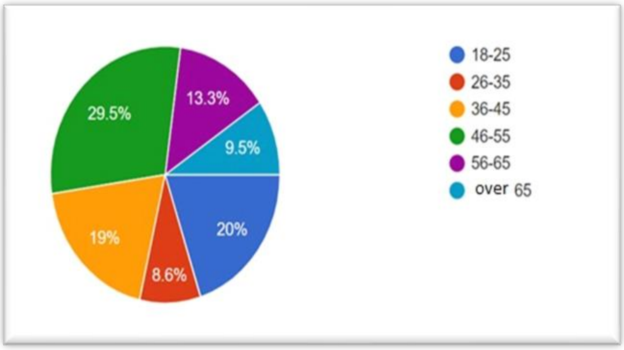

Figure 1. The age of the participants.

A number of 105 subjects between the ages of 18 and 80 took part in the present study. Responses came predominantly from people aged 46-55 (29.5% of total responses), followed by the 18-25 age group (20% of total responses) and the 36-45 age group (19% of total responses). This is important because it gives us a wider range of opinions on the importance of recycling clothing items.

Most of the answers received were given by women, i.e., 87.6% of the total answers, as can be seen in figure 2. It should be noted that statistically, worldwide, women purchase clothing products more often and in larger quantities (Babel and Mehta, 2019).

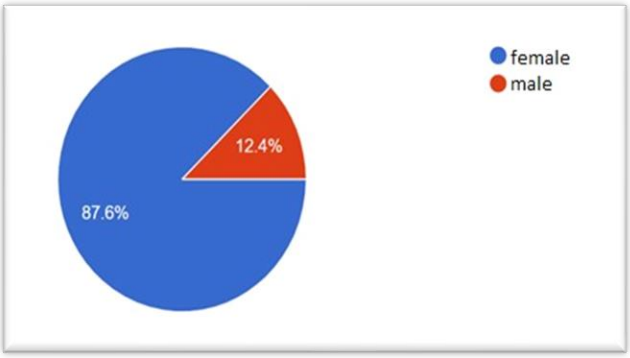

Figure 2. The gender of the participants.

All participants, except for one case (which has only secondary school), have at least completed high school, most of them have completed university studies, as can be seen in Fig. 3 (63.8% of total responses). This is relevant because individuals' educational background and training can often shape their behaviors and attitudes concerning certain subjects, in this case the recycling of clothing items. University studies can provide solid information and knowledge about the benefits of recycling, recycling processes and environmental impact. Consequently, University graduates may be more familiar with the concepts and practices of recycling and have a deeper understanding of its importance.

It should be noted that the level of education is not the only factor that influences recycling behavior. Other factors such as awareness, accessibility of recycling infrastructure and individual motivations can also play a significant role.

It was concluded that all participants live in urban areas, so they have access to the stores of many fashion retailers.

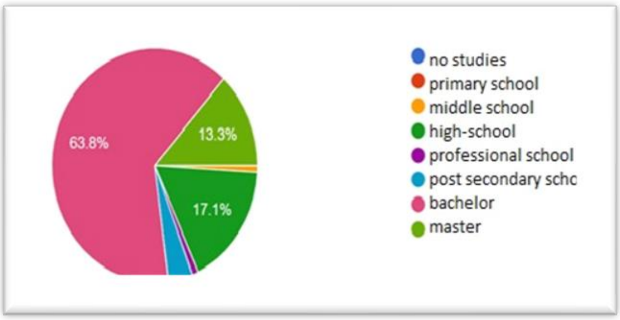

Figure 3. The subjects' education level.

(ii) Research tools

The present research used the survey as a research method, and the questionnaire as a study tool, which was built around the purpose and objectives.

The questionnaire identifies itself as a flexible research tool, allowing the collection of primary data through questions. The questions are structured according to well-defined principles. (Turner, J.R., Simister, J.S., 2004).

Using a questionnaire as a data collection method offers several advantages. This allows for standardized data collection, ensuring that all participants receive the same questions, in the same manner. This helps maintain consistency and comparability in the data collected.

As the questionnaire is in electronic form, it can be distributed to a large number of people simultaneously, making it an effective method of collecting data from a diverse sample. The questionnaire comprises multiple-choice questions, open-ended questions or a combination thereof.

In this case, people were asked to answer the questionnaire, giving opinions and answers to the questions asked. Participants' responses were then compiled and analyzed to gain insights, identify patterns, or draw conclusions related to the research topic.

The questionnaire focused on people's awareness of the importance of recycling clothing items, their preference for types of textile materials and the criteria behind their choice when shopping.

The questionnaire includes a number of 11 items, clear, non-threatening questions being used. The first questions are introductory, of a general nature, having the role of giving the subject confidence both in himself and in the one who carries out the marketing research. One of the questions accesses the subject's memory by being an open question. Both closed, dichotomous and multichotomous scales and scale questions are identified in the questionnaire. The last four questions are identification, being used in the analysis of the questionnaire responses to identify the study participants and to describe the given sample.

Before being implemented on a sample of 5 target subjects, the questionnaire was pre-tested to find out if the questions are clearly stated enough to be understood correctly, if they are understood from all points of view, if they are in the correct order in the questionnaire, as well as if the answers provided are sufficient.

Another aspect tested was the time required to complete the questionnaire.

Following the pretest, changes were made to the questionnaire and the respondents were subsequently excluded from the investigated population.

(iii) Research design and data analysis

The present study is a descriptive, non-experimental, transversal type, which aims to analyze the perception of the population on the importance of recycling clothing items.

The research is non-representative quantitative, without the possibility of extrapolating the results to the entire population, so the research results remain localized at the level of the studied sample. (Ungureşan, 2022)

To obtain the data, we used a sampling method based on accessibility.

RESULTS AND DISCUSSIONS

Participants in the questionnaire were asked to what extent they consider themselves informed about the importance of recycling clothing items. The answers were quite different, only 9.5% of the participants considered that they were very much informed about this topic (Fig. 4).

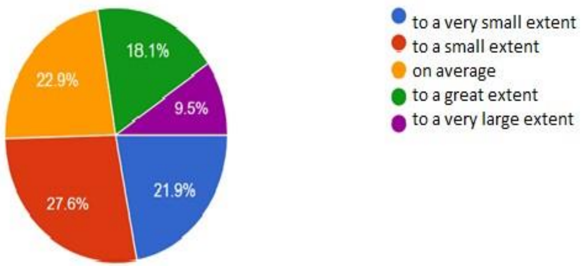

Figure 4. People's awareness of the importance of clothing recycling

Almost half of the subjects, respectively 44.8% of all respondents, did not consider that they were sufficiently informed about this subject, although they expressed their desire to learn more. Many people mentioned that campaigns promoting textile recycling are not popularized enough to reach a wider audience, and in some locations there are no known collection points for used clothing items.

Fast-fashion, characterized by cheap clothes made for short-term use, has contributed to a culture of disposable clothes. The constant cycle of buying and throwing away clothes results in a significant amount of textile waste ending up in landfills. By purchasing clothes less frequently, people can help reduce textile waste and promote a more sustainable approach to fashion.

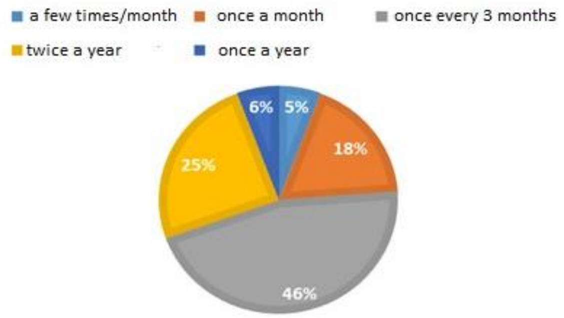

Figure 5. Purchase of new clothing items.

Another aspect that is highlighted is the frequency of purchasing new clothing products. A large percentage of participants, namely 46%, stated that they renew their wardrobe once every three months, and only 5% buy clothes several times a month (Fig. 5). This may also be influenced by differences in income, but the study focuses on the amount of waste that can emerge from the data collected. By purchasing clothing less frequently, people can support ethical and responsible brands that prioritize fair labor practices, thereby helping to promote positive change in the industry.

The criteria behind the choice of clothing items can provide a lot of information about people and can reflect different aspects of their personality and values. Clothing choices reflect a person's personal style and their fashion tastes. Whether it's classic, minimalist, bohemian, sporty or alternative, the way a person chooses to dress can highlight what they like and how they express their individuality through their clothes. Some people emphasize comfort and functionality when choosing their clothes. These people may turn to soft and flexible materials, clothing that allows freedom of movement, and items that fit their specific needs based on the activities they do. For some people, the choice of clothing is based on quality and durability. They prefer clothes made of high-quality materials, well-stitched and durable. They emphasize investing in pieces that will last longer and withstand wear and tear, rather than lower quality clothing or fast fashion products. Alternatively, some people are concerned about the impact clothes have on the environment and society. They can steer their clothing choices towards sustainable and ethical brands that use recycled or organic materials, practice fair labor conditions and promote transparency in the supply chain. Last but not least, some people let themselves be guided by the fashion trends and cultural influences of the moment. They choose their clothes to conform or stand out within a particular style or trend and to connect with contemporary fashion and culture.

The most important criteria for choosing clothing items resulting from the study are the materials from which they are made and their price, as can be seen in Table 1. People are not very interested in the company or the country in which the product is made, but in the price-quality ratio.

Table 1. Criteria for choosing clothing items

The factor impacting clothing choices	Number of subjects	%
Material composition	82	78,1%
Latest fashion trends	9	8,6%
Manufacturer	15	14,3%
Price	61	58,1%
Country of manufacture	9	8,6%
Functionality	6	6,3%

The material preferred by the majority of study participants was cotton, with a weight of 94.3% of the total, followed by linen, with 54.3%, the answer options being multiple (Table 2).

Table 2. Popular textiles

Material	Number of subjects	%
Cotton	99	94,3%
Linen	57	54,3%
Hemp	16	15,2%
Silk	28	26,7%
Velvet	11	10,5%
Satin	9	8,6%
Chiffon	4	3,8%
Synthetics	9	8,6%

The subjects argued the choice made for cotton as follows: several people said that it is the most popular material, which allows the skin to breathe, but offers comfort at the same time; others have claimed that the material lasts longer and performs better in frequent washes. Those who chose linen had similar opinions to those about cotton, choosing a natural fiber considered classic in Romania. Those who chose synthetic materials (8.6%) mentioned that they prefer them for sportswear, because sweat evaporates much faster from them.When the subjects were asked what they do with the clothing items after they no longer use them, the answers varied, but the most common answer was "I donate them to other people" with 89.5% of the participants voting for this option (Table 3).

Table 3. What happens to used clothes

Disposal Method for Used Clothes	Number of subjects	%
Throw them in the trash	9	8,6%
Donate them to other people	94	89,5%
Take them to special clothes collection container	34	32,4%
Return them to stores with special programs for collecting used clothing items	4	3,8%
Burn them	1	1%
Give them new purposes (e..: house cloths)	7	6,67 %

About a third of the participants also indicated that the clothes were taken to a special clothes collection container (32.4%), while others mentioned that they had never seen such a container. This is a wake-up call for the authorities to make it easier for people to access collection points for used textiles.

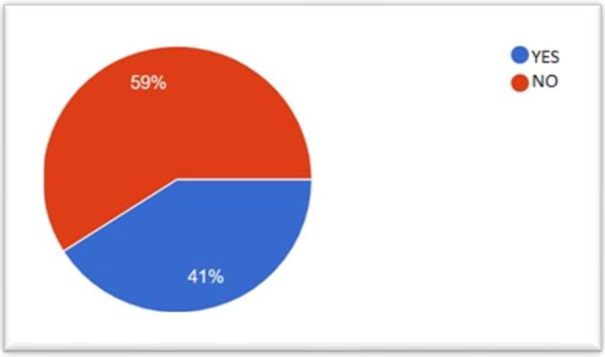

Figure 6. Subjects' awareness of special used clothing collection programs.

Only 3.8% answered that they return clothing items to stores with special campaigns, and only 41% of participants know of their existence (Fig. 6), which suggests that they should be more advertised. Almost a fifth (8.6%) throw away used textiles, turning them directly into waste and contributing to landfill overcrowding.

At the end of the study, it was asked to what extent people consider it important to recycle clothing items. While the majority answered very much (61%) or a great deal (28.6%), there were also some interesting responses. 2.9% of the participants declared themselves completely indifferent to this topic, considering that it does not represent an urgent environmental problem (Fig. 7). While it is good that most people are somewhat concerned about the environment, the existence of disinterested people will continue to be a danger to the environment, continuing to pollute it without restraint.

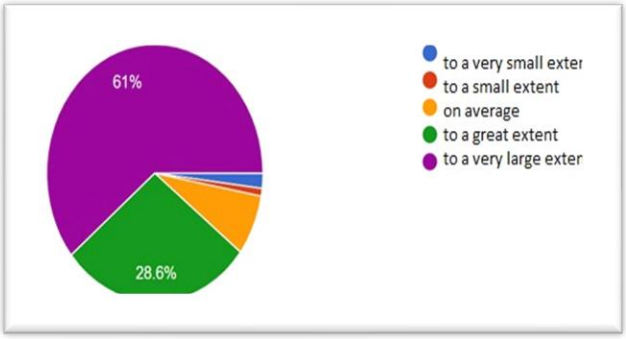

Figure 7. The importance of recycling clothing items.

SWOT ANALYSIS

Strengths:

- 61.7% of respondents consider clothing recycling to be very important.
- Textile recycling is an integral part of the circular economy, which aims to minimize waste and maximize resource utilization. By recycling textiles and creating new products from recycled materials, the industry follows the principles of a closed-loop system, reducing the need for continuous extraction of raw materials.
- Respondents prefer to donate clothing for reuse or place them in special containers for collecting used garments.
- There is an increasing demand from consumers for sustainable and recyclable products.
- Textile recycling encourages innovation and product diversification.

Weaknesses:

- It is observed that study participants purchase clothing at short intervals, caught up in the "fast fashion" trend, thereby generating the most textile waste.
- A large percentage of participants are not informed about the importance of clothing recycling. Limited awareness among people leads to an increase in textile waste volume and limits recycling.
- Not all respondents have access to collection points for used textiles. Infrastructure is insufficient for textile recycling in some regions, leading to difficulties in managing and processing textile waste.
- The high costs associated with the technologies and equipment necessary for efficient textile recycling can discourage investments and innovations in this industry.
- Textile recycling faces challenges related to contamination and sorting of collected materials, as people are not aware of how to recycle properly.

Opportunities:

- Sustainability and eco-friendly options can provide an opportunity for the textile recycling industry to establish itself as a sustainable solution, attracting environmentally conscious customers.
- Governments can adopt new laws on textile recycling and waste reduction, providing incentives for involved companies. These initiatives could support the growth and expansion of the textile recycling industry.
- By transforming old clothes into fashionable garments, textile recycling can meet the demand for recycled products on the market, attracting environmentally conscious consumers who appreciate creativity and originality.
- Advancements in recycling technologies have the potential to enhance the efficiency and scalability of textile recycling processes. Innovations such as advanced sorting and separation, chemical recycling and automation can reduce costs, increase production capacity, and strengthen the global competitiveness of the industry.
- Public education campaigns focused on the benefits of textile recycling can promote a culture of responsible consumption and stimulate demand for recycled textiles.

- Textile recycling has the potential to expand into emerging markets, where sustainable practices and recycling infrastructure are still developing. By entering these regions early, companies can benefit from the growing demand for textiles, promoting sustainable production and waste reduction.

Threats:

- The "fast fashion" industry, characterized by cheap clothing, continues to dominate the market. The constant influx of new and cheap clothes may discourage consumers from opting for recycled textiles.
- Lack of consumer awareness regarding the importance and benefits of textile recycling may slow down the demand for recycled textiles and, consequently, the growth of the industry in this field, even in the context of increasing awareness of environmental issues.
- The production of recycled textiles faces difficulties in meeting consumer expectations, as variations in quality, color, and texture of recycled fibers can make it challenging to produce textiles that meet industry standards.
- The development and implementation of advanced recycling technologies can be costly and require significant investments.
- Economic fluctuations, funding availability, and market demand can affect the viability of textile recycling. Market instability and economic uncertainty can influence the profitability and investment opportunities in the industry.
- Compliance with environmental regulations and waste management policies can add complexity and costs to the textile recycling industry.

CONCLUSIONS

The results provide valuable insights into the concept of sustainable fashion, people's current state of awareness, specific context, geographic location and cultural factors influencing outcomes in different regions and populations.

A large part of the tested sample considers it very important that clothing items are recycled, and around 41% of people are aware of special programs for collecting used clothing. The data shows that most people buy new clothing items on average 3 times a year (about 46% of people). They are followed by those who buy new clothes twice a year (25% of people), and monthly (18% of people). The materials from which the clothing items are made represent the most important criterion in choosing such a product, a percentage of 78.1% of the participants choosing this option. Also, the most popular materials are cotton (94.3%), linen (54.3%), and silk (26.7%). 89.5% of used clothes are "donated to other people". About a third of the participants (32.4%) take them to a special container for collecting clothes.

The main limitation of the research is the impossibility of generalizing the conclusions of the study at the level of the entire country, the subjects tested being only in Cluj County.

The purpose of the research was to obtain information that can be generalized globally, to reach deeper levels of information, to better understand the causes underlying the population's motivation for recycling clothing items, as well as to explain their motivations, attitudes and behaviors.

Another limitation of the research was the impossibility of interacting with the investigated subjects. This may have damaged the sincerity of the respondents. Added to this was the fact that the possible questions that the subjects probably had could not be answered.

In addition, a random sampling was not done, on subjects from all over the country, therefore the results obtained are significant only at the level of the investigated sample or possibly at the level of Cluj County. Another limitation of the research is the short time in which the observation was carried out.

In the legislative context of Romania, especially within the framework of the circular economy, there is an increasing trend towards adopting and implementing policies and regulations that promote sustainable practices in the textile industry. These policies aim to reduce waste, efficiently utilize resources, and encourage recycling and material reuse.

Based on the results of our research and the importance of promoting sustainable fashion and clothing recycling, we make the following policy recommendations:

- Development and implementation of educational and awareness programs for the general public, emphasizing the importance of clothing recycling and its impact on the environment.
- Establishment of a legislative framework to promote and facilitate clothing recycling, including setting clear standards and rules for the textile industry and recycling processes.
- Encouragement of innovation and investment in advanced recycling technologies and processes, through the provision of subsidies and grants for companies adopting sustainable practices.
- Support and promotion of social and solidarity economy initiatives, providing local solutions for clothing collection, sorting, and recycling.
- Introduction of taxes and levies for companies that don't adopt sustainable practices and generate a negative impact on the environment, in order to encourage transition to more responsible business models.

These recommendations could contribute to create a legislative infrastructure and a favorable regulatory framework for the development of a circular economy in the textile industry in Romania, thus reducing environmental impact and promoting sustainable economic development.

There are several possible solutions for improving the situation of textile recycling:

– Education and awareness: Awareness campaigns can be implemented to inform people about the importance of textile recycling and the correct recycling methods.
– Improvement of recycling infrastructure: Expanding the network of collection points for used textiles and investing in recycling facilities can enhance the accessibility and efficiency of the recycling process.
– Promotion of recycled products: Companies and designers can promote products made from recycled materials to stimulate demand and increase awareness of sustainability.
– Technological innovation: Continued research and development in recycling technologies can lead to more efficient and sustainable methods of processing used textiles.
– To further develop the topic in the future, it would be useful to conduct a more detailed analysis of specific issues and local needs. Additionally, collaboration among governments, private companies, non-governmental organizations, and consumers may be essential for implementing effective and sustainable solutions in the field of textile recycling. Promoting continuous research and innovation could also lead to the discovery of new and improved solutions for managing and recycling textiles in the future.

Thus, awareness of textile waste is an essential catalyst for promoting sustainable fashion practices and reducing the negative impact of the fashion industry on the environment. Collective action and commitment from all stakeholders are required to bring about meaningful change and protect our planet for future generations.

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Article

THE INFLUENCE OF EXPIRED MEDICINES ON PLANT PHOTOSYNTHESIS PARAMETERS AND CHLOROPHYLL PIGMENTS

Lucian COPOLOVICI[1,2*], Flavia BORTES[2,3], Brenda SVINTI[1], Andreea LUPITU[3], Cristian MOISA[3], Dana COPOLOVICI[1]

[1]Faculty of Food Engineering, Tourism and Environmental Protection, Aurel Vlaicu University, 2 Elena Dragoi St., Arad, 310330, Romania
[2]Interdisciplinary Doctoral School of Aurel Vlaicu University, 2 Elena Dragoi St., Arad, 310330, Romania
[3]Institute for Interdisciplinary Research, 2 Elena Dragoi St., Arad, 310330, Romania
**Corresponding author: lucian.copolovici@uav.ro*

Abstract:
This study examines the influence of expired pharmaceuticals on Brassica oleracea var. Buzău, grown at three different CO_2 concentrations, focusing on photosynthetic parameters and chlorophyll pigment concentrations. Active pharmaceutical ingredients (APIs) and excipients in expired drugs pose significant environmental and public health risks through improper disposal, leading to soil and water contamination. Pharmaceuticals in the soil significantly impact plant photosynthesis, reducing net assimilation rates and stomatal conductance. Additionally, they cause a marked decrease in chlorophyll a and b concentrations due to toxic effects that degrade chlorophyll and inhibit its biosynthesis. However, an increase in zeaxanthin concentration suggests an adaptive response to oxidative stress. While total phenol concentrations remain relatively unaffected, flavonoid levels significantly decline, disrupting secondary plant metabolism. Elevated CO_2 levels can stimulate phenolic compound synthesis, partially offsetting the negative impacts of pharmaceuticals. The antioxidant activity of plants is also compromised, as indicated by altered inhibition percentages due to reduced phenol concentrations essential for soil microbial activity and chemical reactions. These findings highlight the need for understanding the combined effects of pharmaceuticals and elevated CO_2 on plant health and stress the importance of managing soil contamination to protect ecological health and agricultural productivity.

Keywords: *Brassica oleracea var. Buzău*., abiotic stress, photosynthesis, elevated carbon dioxide.

INTRODUCTION

Active pharmaceutical ingredients (APIs) refer to the biologically active constituents of a medication. Additionally, these components may include additional physiologically active chemicals, typically known as excipients. Excipients are added to several drugs to augment absorption and boost solubility (Kayode-Afolayan et al., 2022). Expired drugs pose a significant issue for both the environment and public health (Begum et al., 2021). Improper disposal of medications, such as indiscriminately discarding them in toilets, sinks, or landfills, can pollute soil (Granger and Nicoll, 2014), groundwater (Ashton et al., 2004), and drinking water sources (Kookana et al., 2014). For example, a study conducted in Kabul, Afghanistan, revealed that out of 301 questionnaires, 77.7% of the respondents disposed of expired medicines in household trash (Bashaar et al., 2017). These pollutants have a detrimental impact on plants and animals, disrupting the ecological equilibrium.

The absorption of medications by plants has been proven on several scales, including laboratory trials and real-life agricultural settings (Garduño-Jiménez and Carter, 2024). The lettuce was grown in a hydroponic system with diclofenac at a concentration of 20 mg/L, and the drug was found in the roots at a very low concentration. However, no diclofenac was identified in the leaves of the *Lactuca sativa* (Bigott et al., 2021). In a preliminary investigation in 2013, Carter et al. conducted a controlled experiment involving radish (*Raphanus sativus*) and ryegrass (*Lolium perenne*). The study aimed to understand the absorption behavior of pharmaceuticals when introduced directly into the soil. The researchers observed that both plant species absorbed five of the six tested pharmaceuticals. They noted that the uptake of these pharmaceuticals was significantly influenced by various physicochemical properties, including the distribution coefficient, which affects the compound's solubility and partitioning behavior. Additionally, soil parameters such as the organic carbon content played a crucial role in determining the extent of pharmaceutical uptake (Carter et al., 2014). Medications can adversely affect aquatic creatures by disrupting their hormones and behavior (Kayode-Afolayan et al., 2022). Additionally, they can hinder the normal breakdown of organic matter and the cycling of nutrients in the soil, which can negatively impact soil fertility and the health of plants (Gerke, 2022). Improperly discarded drugs lead to the emergence of antibiotic-resistant bacteria, which poses a significant concern to public health due to the difficulty in treating infections caused by these bacteria, hence increasing the likelihood of illness and death (Ajayi et al., 2024).

On the other hand, the global concentration of carbon dioxide has increased more than ever in the last ten years, reaching an unprecedented level of 426 ppmv in May 2024. This significant rise in carbon dioxide levels is a cause for concern due to its implications for climate change and environmental health. For plants, such an increase in carbon dioxide concentration could have a dual impact. On the one hand, it could enhance the assimilation rate, which refers to the process by which plants convert carbon dioxide into organic compounds during photosynthesis (Jawahar Jothi et al., 2024). This could potentially lead to increased plant growth and productivity (Siddique et al., 2024). However, this positive effect is counterbalanced by potential negative consequences on the cycles of secondary metabolites. Secondary metabolites are organic compounds that are not directly involved in plants' normal growth, development, or reproduction but play crucial roles in plant defense, signaling, and interactions with their environment (Lupitu et al., 2023). Changes in carbon dioxide levels can disrupt these cycles, leading to altered production of secondary metabolites. This disruption can have far-reaching effects on plant health, resilience, and their ability to cope with stressors such as pests, diseases, and environmental changes (Duan et al., 2024).

The *Brassicaceae* family, also known as the mustard family, is one of the most economically significant families of flowering plants. This family comprises 372 genera and 4,060 accepted species, including many important agricultural crops.

This study aimed to analyze the effect of expired drugs on *Brassica oleracea* var *Buzău* grown at three different concentrations of carbon dioxide, on photosynthetic parameters and chlorophyll pigments concentrations.

MATERIALS AND METHODS

Plant material

Brassica oleracea var *Buzău* seeds were planted in plastic pots filled with commercially available garden soil at a depth of 1 cm. The plants were grown under a day/night cycle with temperatures of 25°C during the day and 18°C at night, with a 12-hour daily light regimen. The plants were exposed to three different concentrations of carbon dioxide: 400 ppm, 800 ppm, and 1200 ppm. Experimental analyses were conducted eight weeks after planting. The plants have been watered with one litter of 0.4 g/L active substance solution of the following drugs: Omeprazole (omeprazole), Espumisan (simethicone), Lipantil (fenofibrate), NoSpa (drotaverine chlorhydrate), Dulcolax (bisacodyl), and Ketonal (ketoprofene), expired from 5 months.

Determination of photosynthetic parameters

A GFS-3000 gas exchange device (Heinz Walz GmbH, Effeltrich, Germany) was utilized to analyze the photosynthetic parameters (assimilation rates and stomatal conductance to water vapor) (Copolovici et al., 2017a; Niinemets et al., 2010).

Determination of chlorophyll pigments

High-performance liquid chromatography (HPLC) was employed to identify and quantify plant chlorophyll pigments. Following exposure to various concentrations of carbon dioxide and ozone, leaf samples measuring 4 cm² were collected and extracted with acetone, following the methodology outlined in (Opriş et al., 2013), to determine chlorophylls a and b and other pigments. The analyses were conducted using a high-performance chromatographic system

(NEXERA8030, Shimadzu, Japan) equipped with a diode array detector (DAD).

The determination of total phenolics and flavonoids

The total phenolic content was determined using the Folin-Ciocalteu method, measuring the complex formed at a wavelength of 765 nm. The flavonoid content was determined based on the reaction with aluminum chloride, measuring the yellow product obtained at 434 nm.

Determination of antioxidant capacity

The spectrophotometric method used DPPH (2,2-diphenyl-1-picrylhydrazyl), a stable free radical, to evaluate the antioxidant capacity of plant extracts. The extracted sample was mixed with a DPPH solution and incubated for a specified time, allowing the reaction between antioxidants and DPPH radicals. A spectrophotometer monitored the formation of the complex between antioxidants and DPPH at a wavelength of 517 nm. The antioxidant capacity was determined by measuring the initial and final absorbance of the solution and calculating the percentage of inhibition of DPPH radicals.

RESULTS AND DISCUSSIONS

Photosynthetic parameters

The photosynthetic parameters of control plants were higher than those of plants grown at elevated carbon dioxide concentrations (Figure 1). The assimilation rate decreases in plants treated with various medicines, particularly those grown at high carbon dioxide concentrations. This phenomenon has been specifically observed in plants treated with common pharmaceuticals such as diclofenac (Copolovici et al., 2017b) and paracetamol (Taschina et al., 2017). Our previous study demonstrated that plants from the *Fabaceae* family significantly reduce the assimilation rate when exposed to different concentrations of nonsteroidal anti-inflammatory drugs (NSAIDs) (Taschina et al., 2022). Elevated carbon dioxide concentrations negatively impact stomatal conductance to water vapor. This phenomenon occurs because plants can minimize water loss by reducing maximal stomatal conductance while still maintaining carbon uptake (Beerling and Franks, 2010).

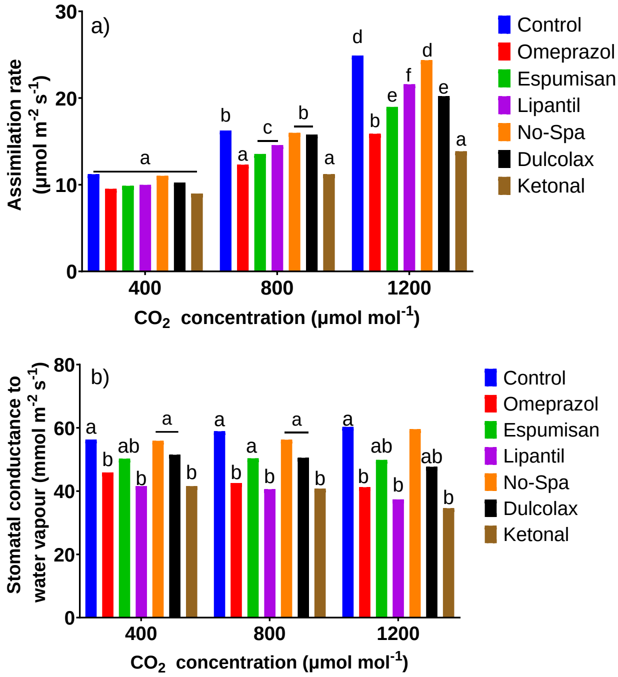


Figure 1. Variation in Assimilation rate (a) and Stomatal conductance to water vapor (b) for *Brassica oleracea* plants grown at high carbon dioxide and treated with 0.4 g medicines. Data sharing different letters are significantly different ($p < 0.05$), while data sharing the same letters are not significantly different ($p > 0.05$).

Additionally, when plants are treated with certain pharmaceuticals, stomatal conductance has a differential response. For instance, treatments with ketonal decrease stomatal conductance, whereas treatments with NoSpa and Dulcolax do not elicit significant changes in this physiological parameter. These findings suggest that the application of these medications can negatively impact the physiological processes of plants, potentially affecting their growth and productivity, especially under elevated carbon dioxide conditions.

The influence of elevated carbon dioxide and drugs on chlorophyll pigments

Chlorophyll pigments, specifically chlorophylls a and b, are adversely affected by the presence of pharmaceuticals in the soil (Figure 2). Conversely, elevated carbon dioxide concentrations increase chlorophyll levels. However, the influence of carbon dioxide is not sufficient to mitigate the adverse effects of the drugs.

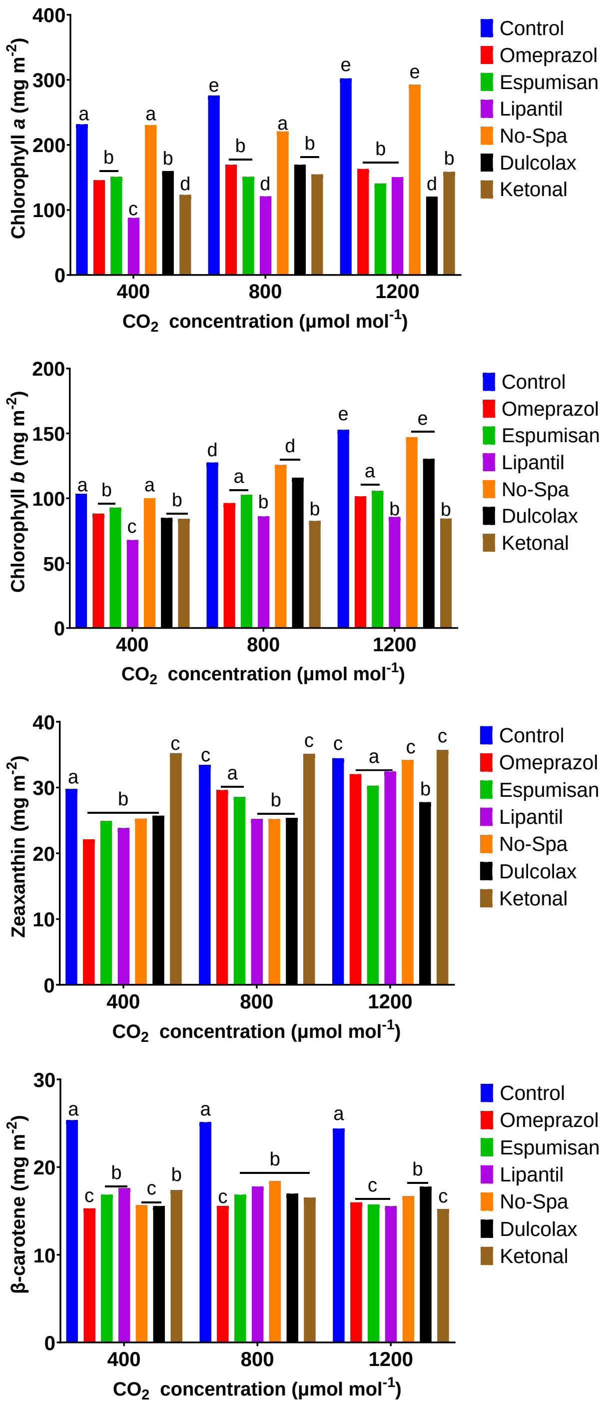
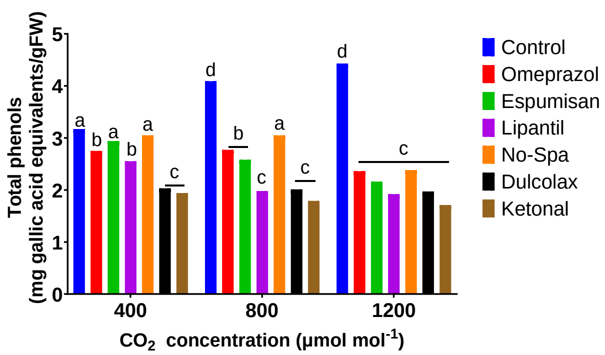


Figure 2. The influence of drugs on chlorophyll pigments in the leaves of plants grown at various CO2 concentrations. Data sharing different letters are significantly different ($p < 0.05$), while data sharing the same letters are not significantly different ($p > 0.05$).

Empirical studies have demonstrated a marked reduction in chlorophyll concentrations within the foliage of plants subjected to various pharmacological treatments (Taschina et al., 2022). This diminution is attributable to the toxicological impacts of these chemical agents on the photosynthetic machinery, resulting in both the degradation of chlorophyll and the inhibition of its biosynthesis (Krupka et al., 2022). Conversely, an upregulation in zeaxanthin concentration has been documented in plants exposed to these pharmaceuticals. Out of the several carotenoids that were found to have varied levels of accumulation, zeaxanthin showed the highest accumulation. This particular metabolite is produced by the oxidation of antheraxanthin by an important enzyme called zeaxanthin epoxidase (Dautermann and Lohr, 2017; Park et al., 2017). This response involves the activation of protective pathways aimed at mitigating oxidative damage. The mechanisms through which pharmaceuticals influence chlorophyll levels encompass interference with both the synthesis and degradation pathways of the pigment, as well as the induction of oxidative stress via the generation of reactive oxygen species (ROS) (Hao et al., 2022). These reactive species precipitate the peroxidation of chloroplast membrane lipids, thereby compromising the structural and functional integrity of chloroplasts.

The influence of drug-induced stress and carbon dioxide on total phenols and flavonoids

While the concentration of total phenols is not strongly affected by the presence of pharmaceuticals, flavonoids show a significant decrease in the presence of these substances (Figure 3). This behavior can be explained by the toxic effect of pharmaceuticals on plants' secondary metabolism, which particularly affects the synthesis and accumulation of flavonoids. On the other hand, the concentrations of total phenols and flavonoids are influenced by the presence or absence of elevated carbon dioxide. Higher concentrations of CO_2 can stimulate the synthesis of phenolic compounds (Ibrahim and Jaafar, 2012), partially compensating for the negative effects of pharmaceuticals on plants.



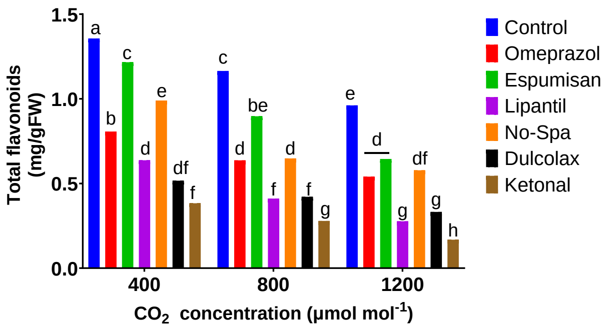


Figure 3. The influence of pharmaceuticals on the concentrations of total phenols and flavonoids in plants grown at different CO_2 concentrations. Data sharing different letters are significantly different ($p < 0.05$), while data sharing the same letters are not significantly different ($p > 0.05$).

Thus, under elevated CO_2 conditions, plants may have a higher antioxidant capacity due to the increased synthesis of phenols and flavonoids.

The influence of pharmaceuticals on the antioxidant activity of plants grown at different CO_2 concentrations

Generally, the percentage of inhibition is altered by the presence of pharmaceuticals in the soil due to decreased phenol concentrations (Figure 4).

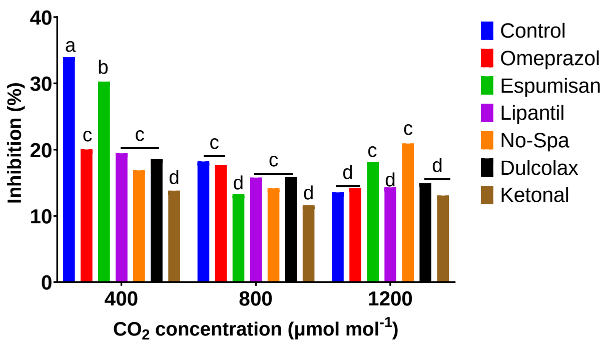


Figure 4. The influence of pharmaceuticals on the inhibition percentage in extracts of plants grown at different CO_2 concentrations. Data sharing different letters are significantly different ($p < 0.05$), while data sharing the same letters are not significantly different ($p > 0.05$).

The presence of pharmaceuticals in the soil can significantly influence various chemical and biological processes. Phenols, aromatic organic compounds, play an essential role in microbial activity and various chemical reactions in the soil. Pharmaceuticals can interact with phenols when introduced into the soil, reducing their concentration.

CONCLUSIONS

The study revealed that the presence of pharmaceuticals in the soil significantly impacts photosynthetic parameters, including net assimilation rate and stomatal conductance. Moreover, pharmaceuticals substantially reduce chlorophyll a and b concentrations in plant leaves, attributed to the toxic effects that degrade chlorophyll and inhibit its biosynthesis. Conversely, an increase in zeaxanthin concentration was observed, suggesting an adaptive response of plants to oxidative stress. While the concentrations of total phenols are not markedly affected by the presence of pharmaceuticals, flavonoids exhibit a significant decline, thereby impacting the secondary metabolism of plants. Elevated CO_2 concentrations have the potential to stimulate the synthesis of phenolic compounds, partially mitigating the adverse effects of pharmaceuticals. The antioxidant activity of plants is also compromised, with the inhibition percentage being modified due to the reduction in phenol concentrations, which are crucial for microbial activity and chemical reactions in the soil. These findings underscore the importance of comprehending the combined effects of pharmaceuticals and elevated carbon dioxide levels on plants. They also emphasize the necessity for meticulous management of soil contamination to safeguard ecological health and maintain agricultural productivity.

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Article

CHARACTERIZATION OF BEESWAX-BASED OLEOGELS WITH PUMPKIN SEED OIL AND RAPESEED OIL

Simona PERȚA-CRIȘAN[1], Claudiu-Ștefan URSACHI[1], Iolanda TOLAN[1], Bianca-Denisa CHEREJI[1], Dumitru CONDRAT[1], Maria BALINT[1], Florentina-Daniela MUNTEANU[1*]

[1]Faculty of Food Engineering, Tourism and Environmental Protection, "Aurel Vlaicu" University, Romania, 2 Elena Dragoi, Arad 310330, Romania
Corresponding author email: florentina.munteanu@uav.ro

***Abstract:** The present research studied some oleogels based on cold-pressed pumpkin seed oil (PO), refined rapeseed oil (RO), and their mixtures in different combinations: PO:RO (3:1) and RO:PO (1:1), formulated with 7% and 10% beeswax (BW) as oleogelator. Several physicochemical properties were analysed, such as crystal formation time (CFT) and oil bonding capacity (OBC), along with oxidative stability, texture and sensory properties. The developed oleogels based on PO and PO:RO (3:1) with 10% BW were found to be stable regarding texture and oxidation, exhibiting high OBC and good consumer acceptability.*

Keywords: oleogel; oleogelator; beeswax; pumpkin seed oil; rapeseed oil

INTRODUCTION

Oleogels are an innovative form of structured oils that have recently gained significant attention in food science and nutrition. They are semi-solid systems where an oil phase is immobilized within a three-dimensional network. This network is formed by the molecules of oleogelators, which can trap large amounts of oil and transform the liquid oil into a gel-like structure (Sivakanthan et al, 2023). Oleogelators include waxes, cellulose derivatives, fatty alcohols, and specific proteins or carbohydrates. Oleogels have a wide range of applications, particularly in the food industry as animal fat replacers, but with an obvious extension to pharmaceuticals and cosmetics (Sivakanthan et al., 2022). Recent studies have mentioned the applicability of oleogels as fat replacers in bakery products, spreads, confectionery, meat products, ice cream, sauces, and dressings (Liu et al., 2024). These applications capitalize on oleogels' ability to structure oils, improve stability, control texture, and provide healthier alternatives to traditional solid fats.

A large amount of evidence from the scientific literature shows that the structure and properties of oleogels are strongly affected by their two components, namely oils and oleogelators, as well as the interactions between them (Sivakanthan et al., 2023). Beeswax is one of the most studied oleogelators due to its ability to gel at low concentrations. In addition, beeswax offers a natural solution for structuring oils, aligning with clean-label trends and healthier fat alternatives in food products. Its compatibility, applicability, and high efficacy make it a valuable tool in food science (Gao et al., 2021).

Several types of vegetable oils have been used for the preparation of oleogels. However, to our knowledge, oleogels based on pumpkin seed oil have been little studied, and oleogels based on mixture of pumpkin seed oil with rapeseed oil not at all.

The pumpkin seed oil has gained popularity recently for its unique flavour profile and potential health benefits. This oil, extracted from pumpkin seeds, has various applications in the food industry. Several studies emphasize its beneficial health effects, such as preventing prostate enlargement and cardiovascular disease, reducing inflammation or improving diabetes (Borriello et al., 2021). These positive health effects are attributed to the abundant presence of bioactive compounds such as essential fatty acids, sterols, polyphenolic compounds and vitamin E (Singh et al., 2023).

Rapeseed oil, extracted from the seeds of *Brassica napus* or *Brassica rapa* (Banaś et al., 2023), is known in two varieties: canola oil, with reduced levels of erucic acid, and tradition al rapeseed oil or "virgin rapeseed oil" (Chew, 2020). By its chemical composition, rapeseed oil is considered an essential source of unsaturated fats, with a balanced ratio of omega-6 and omega-3 fatty acids and vitamins E and K (Amiri et al., 2020).

Due to the high nutritional value and complementary sensory properties of pumpkin seed oil (nutty and woody flavour, deep green colour) and rapeseed oil (light, neutral flavour and colour), we have considered these oils optimal for obtaining oleogels with suitable sensory, textural and technological properties. Therefore, this study aimed to formulate and characterize new beeswax-based oleogels prepared with pumpkin seed oil used alone and in different combinations with rapeseed oil, suitable for substituting saturated fats in various food products.

MATERIALS AND METHODS

Materials

The lipid sources, including cold-pressed pumpkin seed oil (PO) and refined rapeseed oil (RO), were carefully selected for their unique properties and potential to yield diverse results. These were bought from local markets in Arad, Romania. Food-grade beeswax (BW) was obtained from Sigma-Aldrich (Germany). All chemicals used in this study, including sodium thiosulfate, chloroform, acetic acid, thiobarbituric acid, potassium iodide, trichloroacetic acid, and 1,1,3,3-tetra-methoxypropane were of analytical grade and purchased from Sigma-Aldrich ltd. (Germany), Merck (Germany) or Carl Roth (Germany).

Preparation of the oleogels

Oleogel samples were obtained using two different BW concentrations, as follows: 7% (OG7) and 10% (OG10). For oleogelation, PO and RO were used alone and in varied combinations, as indicated in Table 1.

Table 1. Oleogels formulation

Sample code	BW [%]	PO [%]	RO [%]
P-OG7	7	100	0
R-OG7	7	0	100
RP-OG7	7	50	50
PR-OG7	7	72	25
P-OG10	10	100	0
R-OG10	10	0	100
RP-OG10	10	50	50
PR-OG10	10	72	25

To prepare the oleogels it was applied the method described in the scientific literature (Gao et al., 2021; Han et al., 2022), schematically represented in Figure 1.

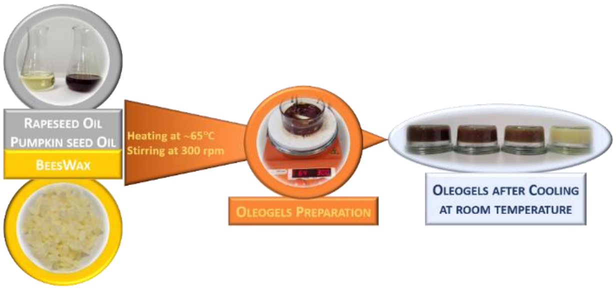


Figure 1. Oleogels preparation

Thus, BW was directly dispersed into preheated oils to ~65°C, under constant stirring at 300 rpm, until a clear solution was obtained. The samples were then cooled at room temperature for 24 h to form the gels (Figure 2) and stored at 4°C until specific physicochemical, textural, and sensory analyses were performed. All determinations were performed in triplicate.

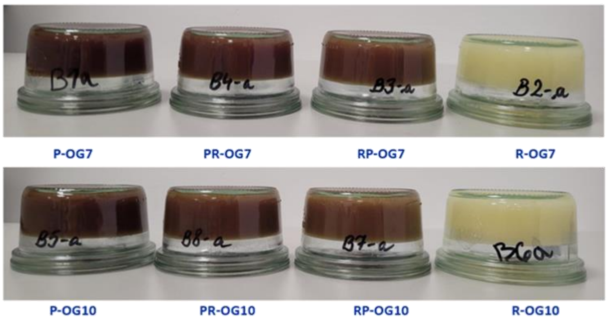


Figure 2. Oleogels formulated with BW

Crystal formation time

The crystal formation time (CFT) method, a crucial aspect of our research, was applied under controlled conditions to identify the time required for the oils to solidify due to the formation of the beeswax crystalline network. CFT was determined by completely pre-melting the oleogels placed in glass tubes in a water bath at 70°C for 1 hour. The time to complete gelation at room temperature (21±3°C) was then measured in minutes, while the tubes were rotated 180° to observe the flow (Keskin et al, 2021).

Oil binding capacity

Oil binding capacity (OBC) is a quality parameter of oleogels that indicates the ability of the gel structure to retain the liquid phase. The OBC was determined for the formulated samples by subjecting them to a centrifugal force under controlled speed, time and temperature conditions. The method described by Giacomozzi et al. (Giacomozzi et al., 2021) was adopted with some modifications and applied.

Approximately 15 g of freshly prepared oleogel samples were accurately weighed into previously tared Falcon tubes. After 24 hours, the oleogels stored at room temperature were centrifuged at 10000 rpm for 15 min at 20°C. After centrifugation, the tubes were inverted for 30 min, the separated oil was decanted, and the samples were weighed again.

Calculation of OBC was performed using the equation (1) (Borriello et al., 2021):

$$\mathrm{OBC}\ (\%) = \left[1 - \frac{(m_1 - m_2)}{m_1}\right] \cdot 100 \quad (1)$$

where m_1 and m_2 represented the mass of the samples before and after centrifugation, respectively.

Oxidative stability

The lipid oxidation of oleogels was evaluated at 24 h after obtaining (T0) and periodically after 7 (T1), 14 (T2) and 21 (T3) days during storage under accelerated oxidation conditions (50°C). The peroxide value (PV) and thiobarbituric acid reactive substances (TBARS) were determined to evaluate the degree of primary and secondary oxidation products. As part of a comprehensive assessment, the oxidative stability was also compared for fresh oil samples: pumpkin seed oil (PO), rapeseed oil (RO), PO:RO 3:1 mixture (PRO), and PO:RO 1:1 mixture (RPO).

The peroxide value (PV) was determined to quantify the amount of peroxides and hydroperoxides formed in the initial stages of lipid oxidation. The method is based on the oxidation of potassium iodide by the peroxides present in the oil sample, releasing iodine, which is then titrated with sodium thiosulfate (Jadhav et al., 2022). This was carried out according to the AOCS Official Methods (Giacomozzi et al., 2021). The process involved dissolving oil or oleogel samples in an acetic acid/chloroform mixture (3:1), adding saturated potassium iodide, homogenizing, and keeping it for 15 minutes in the dark. Titration was then carried out with sodium thiosulfate (0.01 N) using 1% starch as an indicator. The PV was calculated by equation (2) (Millao et al., 2023):

$$\mathrm{PV} = \frac{V \cdot N \cdot 1000}{w} \quad (2)$$

where V represented the volume of sodium thiosulfate (mL), N the normality of sodium thiosulfate, and w the sample weight (g).

TBARS (mg malondialdehyde (MDA)/Kg oil) is another important technique to assess lipid oxidation. It measures secondary oxidation products, mainly MDA, formed during the oxidation of polyunsaturated fatty acids. MDA reacts with thiobarbituric acid under acidic conditions and high temperatures to form a pink-colored complex that can be measured spectrophotometrically (Pan et al., 2021). BARS were determined according to the method described by Pan et al. (Pan et al., 2021).). Briefly, 0.5 g of the sample was mixed with 8 mL of TBARS reagent until it was dissolved. The mixture was heated at 100°C for 15 min. After cooling at room temperature, it was centrifuged at 8000 rpm/20 min (Rotina 380R, Hettich, Germany). The lower phase was separated, and the absorbance was measured at 532 nm (Shimadzu UV-2250, Tokyo, Japan). The results were expressed as mg MDA equivalents per kg sample, using a standard curve prepared with 1,1,3,3-tetraethoxypropane.

Texture

The textural properties of the oleogels were measured by applying a Direct Compression – Relaxation – Traction test using the TX-700 Texture Analyzer (Lamy Rheology Instruments, France), equipped with a 50 N load cell and a 12.7 mm diameter stainless plunger. After preparation, the oleogel samples were placed in polypropylene containers (63 mm height, 40 mm inner diameter), and after gelation at room temperature, they were stored at 4°C. The texture evaluation was performed with the following working parameters: compression speed 1 mm/s; relaxation time 10 s; penetration depth 6 mm; lifting speed 1 mm/s (Pang et al., 2020; Sarkisyan et al., 2023). The maximum force after compression, the equilibrium force after relaxation and the retention force of oleogels when lifting the plunger were measured and recorded. Textural parameters were evaluated by using the associated Rheo Tex software.

Sensory analysis

The sensory analysis was performed only on the oleogels with 10% BW, considering their more stable structural characteristics. Quantitative descriptive analysis (QDA) methodology was applied to ten trained panelists by quantifying some specific descriptive sensory attributes on a 5-point intensity scale (0 - minimum intensity → 5 – maximum intensity). A 9-point hedonic scale (1 – dislike extremely → 9 - like extremely) was used to identify 21 naive consumers' perceptions of the formulated oleogels. A control was also subjected to sensory analysis, meaning pork lard (L-C). XLSTAT Sensory software was used to interpret the statistical data.

RESULTS AND DISCUSSION

Crystal formation time

The gelation behavior of the oleogels was consistent in all samples. Crystal formation time ranged from 7.00 to 8.30 (±0.50) minutes. The values fluctuated between samples due to the different compositions of oleogels in the oils and BW concentrations, which affected crystal formation times and, thus, the gelation process. As shown in Figure 3, increasing the BW concentration from 7 to 10% reduced CFT from 8.15 min to 7.00 min for P-OG and from 8.30 min to 7.15 min for PR-OG. Also, CFT was influenced by the type of oils and their mixing in different proportions, with a lower value observed in the gelation time of pure oils compared to their mixtures.

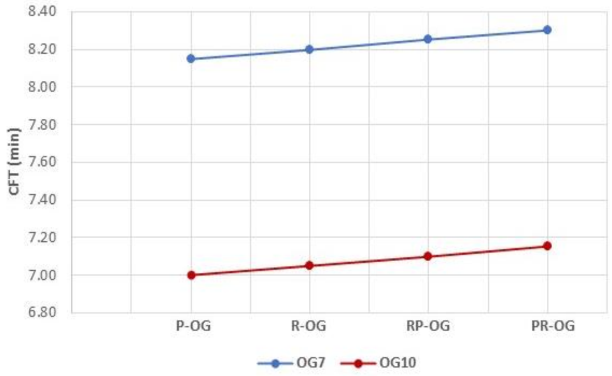


Figure 3. CFT of BW formulated oleogels

Oil binding capacity

The OBC results for the prepared oleogel samples are shown in Figure 4.

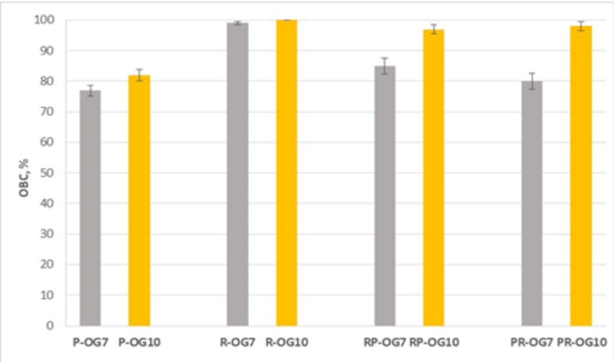


Figure 4. OBC of BW formulated oleogels

All formulated oleogels indicated high levels of OBC, which depended on the type of oil and clearly on the concentration of BW. The OBC values of the prepared oleogels were found to be higher with increasing BW concentration. The OBC was also influenced by the type of oil. P-OG7 and P-OG10 oleogels, formulated with cold-pressed and unrefined PO, showed significantly lower OBC (77% and 82%) than R-OG7 and R-OG10 oleogels, formulated with refined RO (99% and 100%). The OBC of oleogels based on the mixture of the two oils was also higher than those containing only PO.

Oxidative stability

Figure 5 shows the PV evolution of oils and oleogels during storage. The initial PV of the oils and oleogels (T0) was between 1.48 meq O_2/kg oil (RO) and 4.45 meq O_2/kg oil (RP-OG10), suggesting that the primary oxidation levels were low. It can be noted that all the oleogel samples showed higher PV compared to the oils, probably because the oils were heated at 65°C through the oleogel preparation.

During storage at T1, a linear increase of PV can be observed for all the samples. The results showed that PO (3.15 meq O_2/kg oil) was the most stable oil, while P-OG10 (3.15 meq O_2/kg oil) was the most stable oleogel. The highest PV was recorded for RP-OG7 (7.53 meq O_2/kg oil). Still, this value is lower than the maximum limit for edible oils by international regulations (10 meqO_2/kg oil) (Pignitter et al., 2016).

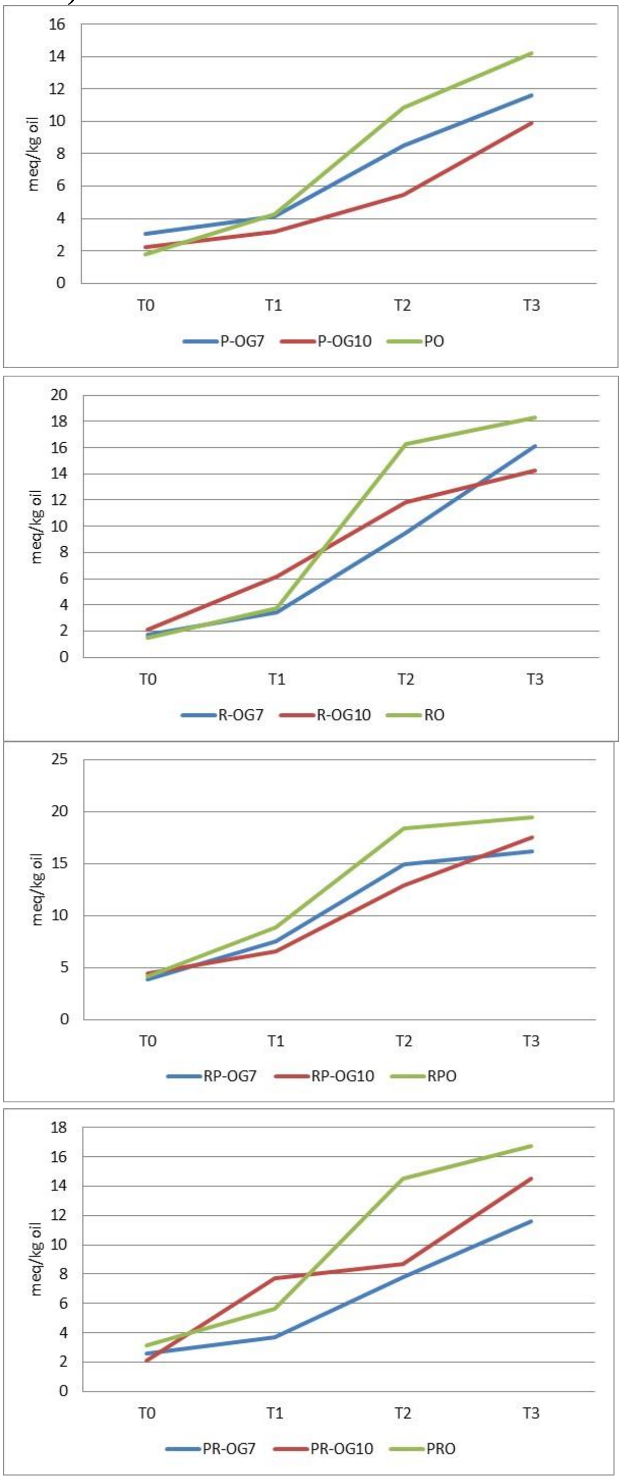
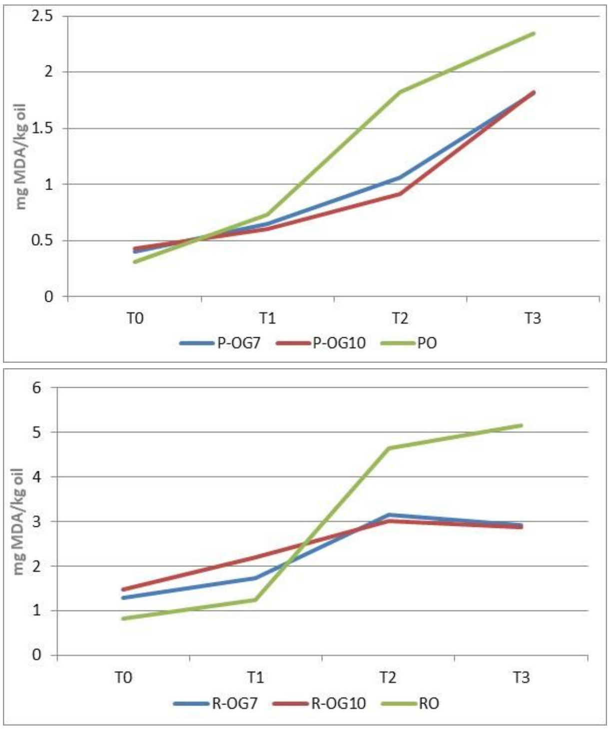


Figure 5. Changes in PV of formulated BW oleogels during storage at 50°C

PV significantly increased for all samples at T2 due to accelerated oxidation processes. For all the oil samples and some oleogels, such as RP-OG7 (14.95 meq O_2/kg oil), RP-OG10 (12.86 meq O_2/kg oil) and R-OG10 (11.81 meq O_2/kg oil), PV exceeded the acceptability level. PV continued to increase for all samples during storage and recorded maximum values when T3 was reached, exceeding the acceptability limit in all cases. After storage, PV for all oleogels was lower than that of oils, due to the the compact structure of BW oleogels that reduced the oxygen permeability and diffusion rate within the samples.

Figure 6 shows the changes in TBARS values of the samples during storage at 50°C.



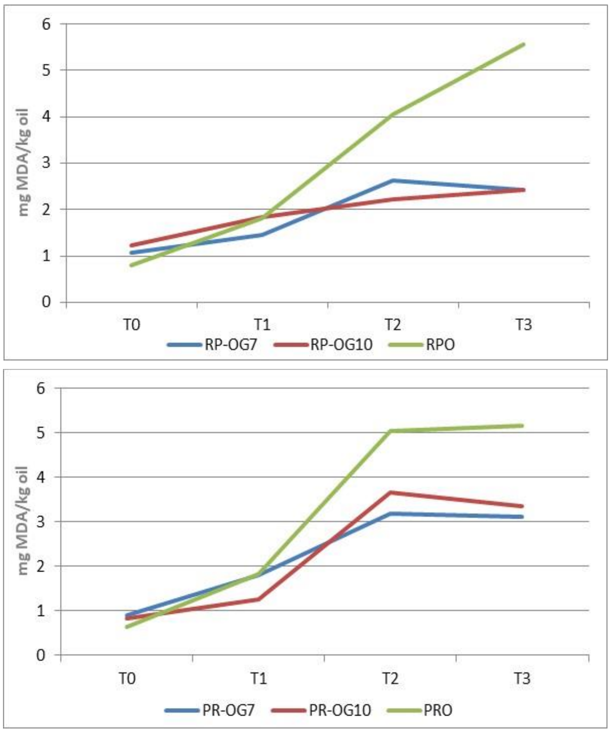


Figure 6. Changes in TBARS values of formulated BW oleogels during storage at 50°C

It can be noticed that TBARS values increased for all samples as a result of the secondary oxidation steps of lipids. In addition to PV, the increasing rate of TBARS values of oleogels was slower than that of oils. This demonstrated that the compact and dense structure of the BW network slowed the transfer rate of oxygen, thus preventing the secondary oxidation processes.

Texture

Texture is an essential property of oleogels, which are used as fat replacers in food products (Tan et al., 2023). The texture of oleogels is influenced by several parameters, including the type of oil due to its fatty acid composition, oleogelator concentration, and working conditions (Frolova et al., 2022; Sarkisyan et al., 2023).

Figure 7 presents the texture parameters obtained for the BW oleogel samples, measured at 5°C. As can be observed, textural properties were significantly influenced by oil type and oleogelator concentration. In line with other authors (Zbikowska et al., 2022), the results showed a high correlation between oleogel firmness and BW concentration. Regardless of oil type, 10% BW oleogels showed significantly higher firmness and better mechanical properties than 7% BW oleogels. Differences were also found in the firmness of BW oleogels depending on the type of oil. R-OG10 was the firmest gel (3.25 N), while P-OG10 was considerably softer (1.05 N). The combination of PO and RO induced firmness values as a function of the mixing ratio. PR-OG10 (2.36 N) showed higher firmness than P-OG10 (1.05 N) and RP-OG10 (1.56 N).

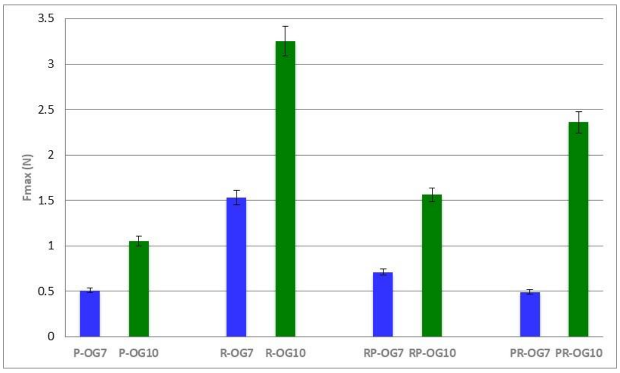


Figure 7. Firmness of formulated BW oleogels

Sensory analysis

The QDA applied on the oleogels with 10% BW led to the quantification of 15 sensory attributes, as shown in Figure 8. Significant differences between the samples were recorded for most descriptors, except those related to mouthfeel, rancid taste and granularity (α=0.05).

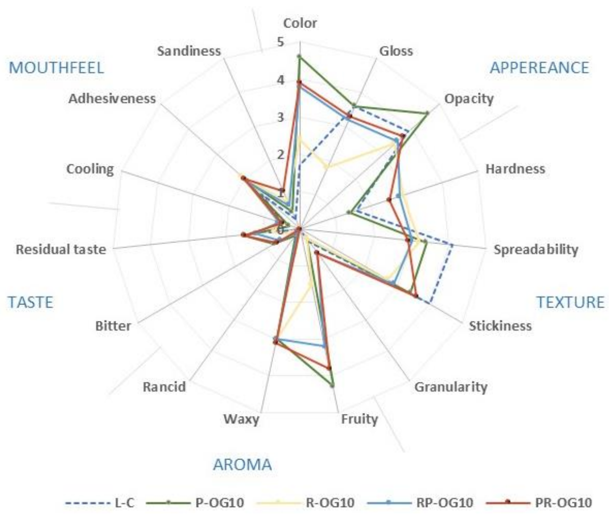


Figure 8. Sensory profile of oleogels formulated with 10% BW

According to Figure 9, the oleogel based on pumpkin seed oil was the most appreciated by consumers, with a score close to that of the control sample (pork lard). The Tukey's comparison test revealed significant differences (95% confidence level) between the hedonic scores of the oleogel based on rapeseed oil (R-OG) and the samples where pumpkin seed oil was predominant (P-OG and PR-OG), respectively, between the score of the control (L-C) and that of the samples where rapeseed oil was found in a larger quantity (R-OG and RP-OG). It should be noted that all the oleogels exceeded the acceptability value limit of 5.

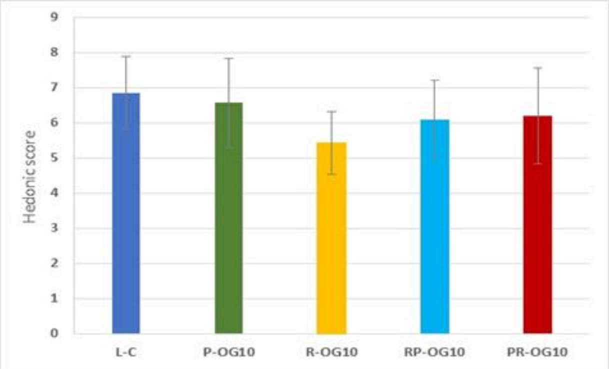


Figure 9. Hedonic scores of oleogels formulated with 10% BW

However, the hedonic scores were low, a situation explained by the fact that the formulated oleogels were not food products by themselves but food components to be incorporated as substitutes for animal fats in foodstuff.

CONCLUSIONS

Beeswax-based oleogels formulated with cold-pressed pumpkin seed oil, rapeseed oil, and combinations were successfully prepared and characterized. Considering the next objective of our research, namely the incorporation of these oleogels in various meat products, it was concluded that the oleogels prepared with 10% BW and based on pumpkin seed oil, respectively, on the mixture of pumpkin seed oil and rapeseed oil in a ratio of 3:1, represent the optimal formulations to obtain stable oleogels with suitable textural profiles, high OBC, adequate oxidative stability, and good consumer acceptability.

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Article

ANALYZING THE VARIATIONS IN POLLUTION LEVELS FOUND IN MEDICAL FACILITIES

Lucian COPOLOVICI[1,2*], Marinela BRENDEA[1], Andreea LUPITU[3], Flavia BORTES[2,3], Cristian MOISA[3], Dana COPOLOVICI[1]

[1]Faculty of Food Engineering, Tourism and Environmental Protection, Aurel Vlaicu University, 2 Elena Dragoi St., Arad, 310330, Romania
[2]Interdisciplinary Doctoral School of Aurel Vlaicu University, 2 Elena Dragoi St., Arad, 310330, Romania
[3]Institute for Interdisciplinary Research, 2 Elena Dragoi St., Arad, 310330, Romania
**Corresponding author: lucian.copolovici@uav.ro*

Abstract:
This study investigates indoor air quality (IAQ) in a small medical family doctor facility, focusing on particulate matter (PM_1, $PM_{2.5}$, PM_{10}), formaldehyde, and total volatile organic compounds (TVOCs). Over five days, measurements revealed that indoor pollutant levels often exceeded those outdoors, with PM concentrations increasing throughout the week due to indoor activities and inadequate ventilation. Formaldehyde levels ranged from 21 to 100 $\mu g/m^3$, peaking in the doctor's office on Thursdays and Fridays and mid-week in other rooms. Outdoor TVOC levels were low and stable, while indoor levels were highest in the treatment room and doctor's office. These findings underscore the need for effective IAQ management to ensure a healthy environment for patients and healthcare workers.

Keywords: Indoor pollution, total volatile organic compounds, particulate matter, formaldehyde, medical office.

INTRODUCTION

Recent studies on human exposure to indoor air pollution have shown that indoor environments can be at least twice as polluted as outdoor ones (González-Martín et al., 2021). In fact, the air on a moderately busy urban street could be cleaner than the air inside a living room (Zhu et al., 2021). Traditionally, indoor air pollution has received much less attention than outdoor air pollution, particularly in heavily industrialized or high-traffic areas (Saraga et al., 2024). However, the risks associated with long-term exposure to indoor air pollution have become more apparent in recent years (Tran et al., 2020). This is because buildings are increasingly sealed off from the outside environment to save on heating and cooling costs. Many buildings now rely entirely on mechanical ventilation, which recirculates indoor air with minimal dilution from outside air, resulting in a buildup of indoor pollutants (Marć et al., 2018). A recent commission report estimated that nearly 3 billion people worldwide are exposed daily to poor indoor air quality (IAQ) due to using solid fuels for cooking, heating, and lighting (Fang et al., 1998).

Indoor pollutant levels can be up to five times, or even 100 times, higher than outdoor pollutant levels, raising significant concerns given that the average individual spends approximately 90% of their time indoors (Ibrahim et al., 2022). Efficient air quality management in hospitals or other medical institutions is essential for preventing infections, especially for patients with weakened immune systems (Śmiełowska et al., 2017). Additionally, it is necessary for maintaining healthcare workers' health, productivity, and well-being (Ibrahim et al., 2022). Various aspects of healthcare facility design, including spatial dimensions, building envelope design, ventilation system design, and outdoor air intake, have been demonstrated to influence indoor air quality (IAQ).

The management of hospital hygiene has a significant role in determining indoor air quality (IAQ) by impacting the levels of indoor pollutants. Inconsistent cleaning methods lead to accumulating particulate matter (PM), which can be stirred up again as building inhabitants walk around, especially when PM levels are high (Yau and Chew, 2009). Engaging in hospital-specific activities and therapies, such as handwashing in sinks, utilizing medicinal sprays, administering nebulization therapy, changing beds, and completing housekeeping tasks, has been demonstrated to impact the concentration of particles and total volatile organic compounds in indoor air (Pereira et al., 2017). Furthermore, using electronic devices such as copiers, printers, and computers for hospital administration may emit benzene, toluene, ethylbenzene, and xylene (BTEX) compounds, which are highly toxic to hospital occupants (Elke et al., 1998). Formaldehyde is extensively utilized in medical settings globally, primarily for tissue preservation in pathology laboratories, as a sterilizing agent and disinfectant (Ghasemkhani et al., 2005). Possible formaldehyde sources in the employment environment's nonexposed sections include pressed wood products, adhesives, varnishes, furniture, and carpets (Salthammer et al., 2010).

This study aims to determine total volatile organic compounds (TVOCs), formaldehyde, and particulate matter levels in different rooms of a small medical family doctor facility.

MATERIALS AND METHODS

The samples were collected from a family medicine practice (located in Bistrita, Romania) with four rooms: file room, waiting room, treatment room, doctor's office, and outdoors. The Dienmern DM 106 multiparameter analyzer (China) was used to measure the concentrations of total volatile organic compounds, formaldehyde, as well as suspended particles of PM_1, $PM_{2.5}$, and PM_{10}, following the same procedure as in (Tepeneu et al., 2023). The samples were collected over five days, from June 10-14, 2024, with a minimum of 4 daily determinations. Statistical analysis of the data was performed using GraphPad Prism version 10.3.0.

RESULTS AND DISCUSSIONS

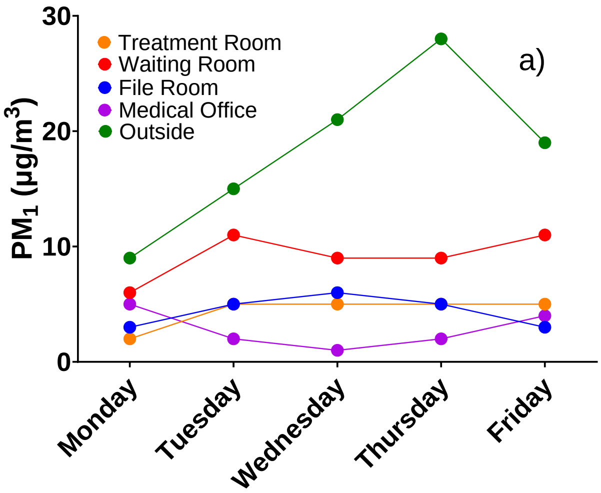
The concentrations of suspended particles determined over one week are presented in Figure 1. The data indicate particulate matter (PM) levels in the air, categorized into different sizes: PM 1, PM 2.5, and PM 10. These measurements provide insight into air quality within the medical facility over the specified period.

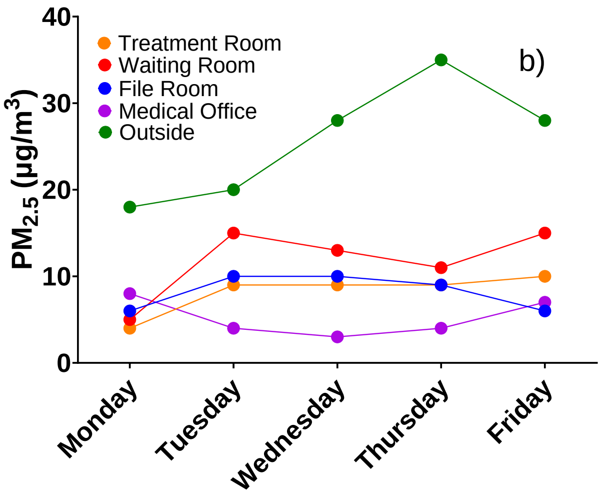
Regarding the values obtained for the outdoor air, it was found that the concentrations are at the limit of the maximum allowable value. This high concentration is understandable given the context of the measurements. The sampling was conducted right in front of the medical office, which is located in a heavily trafficked area. High traffic typically results in elevated levels of air pollutants, including particulate matter, due to vehicle emissions. Thus, the outdoor air quality around the medical office is significantly influenced by the vehicular activity in the vicinity.

For the indoor air, an increase in concentrations of suspended particles is observed during the week for three rooms: the file room, waiting room, and treatment room. This trend suggests that particulate matter accumulates over time, potentially due to indoor activities, human presence, and possibly inadequate ventilation or filtration systems that fail to remove the particles from the indoor environment effectively. It is important to note that various activities within these rooms, such as patient interactions, cleaning, and treatment procedures, can contribute to generating and suspending particulate matter.

In contrast, the concentrations of suspended particles in the doctor's office show a different pattern. Here, the concentrations are higher, specifically on Monday and Friday. This variation might be attributed to several factors. One plausible explanation is the influx of air from the outside, which might be more pronounced these days due to increased opening of doors and windows or higher patient turnover. Additionally, the doctor's office might experience specific activities on these days that contribute to the higher particulate matter levels, such as particular treatments or cleaning routines.

Indeed, the ratio between the indoor and outdoor concentration values for particulate matter is less than one for all three fractions (PM 1, PM 2.5, and PM 10). This indicates that indoor air has lower concentrations of suspended particles than outdoor air (Fan et al., 2020). While this is generally positive, as it suggests some level of protection from outdoor pollution, it also highlights the facility's need for effective air quality management. The fact that outdoor conditions influence indoor air quality underscores the importance of proper ventilation and filtration systems to minimize the infiltration of outdoor pollutants and maintain a healthy indoor environment (Zhou and Yang, 2022).





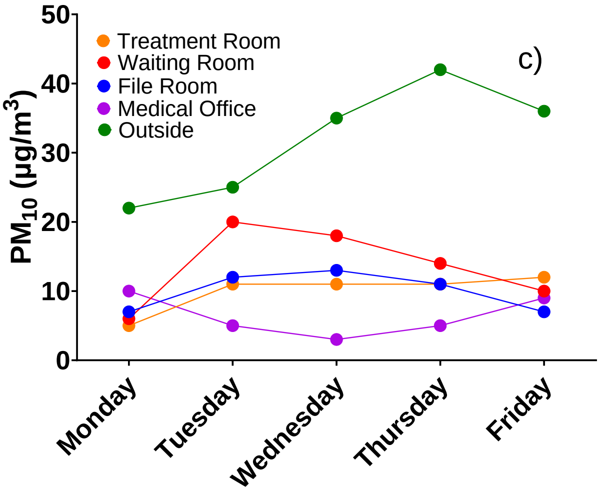


Figure 1. Daily variations in PM_1 (a), $PM_{2.5}$ (b), and PM_{10} (c) concentrations over one-week measurements in 4 different rooms and outside.

The data revealed a distinct pattern across the four examined rooms within the medical facility in the context of formaldehyde concentrations. Formaldehyde is classified as a Group B2 probable human carcinogen under the Integrated Risk Information System (IRIS) of the United States Environmental Protection Agency (EPA), indicating its potential health risks, including respiratory ailments, skin irritation, and carcinogenicity with prolonged exposure. Figure 2 provides a graphical representation of these variations, elucidating the temporal dynamics of formaldehyde concentrations within the facility and pinpointing specific periods of elevated levels.

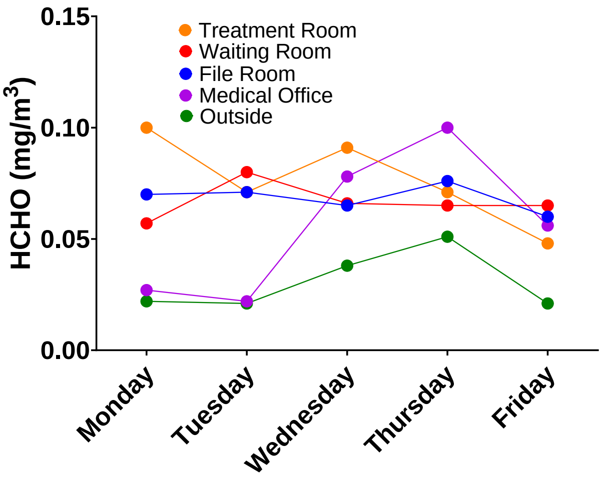


Figure 2. Daily variations in formaldehyde concentration over one-week measurements in 4 different rooms and outside.

The formaldehyde concentrations measured within the medical facility ranged from 21 to 100 μg/m^3. Notably, this upper limit is at the threshold of 100 μg/m^3, the maximum allowable concentration for public-use facilities, underscoring the necessity for vigilant monitoring and mitigation strategies to safeguard occupant health. Disaggregating the data by room reveals varied temporal patterns in formaldehyde concentrations, with the doctor's office exhibiting higher concentrations on Thursday and Friday. This temporal variation could be attributed to specific end-of-week activities or increased utilization of materials and products that emit formaldehyde, such as certain cleaning agents, disinfectants, or medical supplies used more intensively. In contrast, the file, waiting, and treatment rooms generally showed higher formaldehyde levels mid-week. This mid-week increase might result from cumulative daily activities, augmented patient interactions, and routine maintenance procedures that involve formaldehyde-emitting substances. The formaldehyde concentration outside the building remained constant at approximately 30 μg/m^3, contrasting with the fluctuating indoor levels and highlighting the significant influence of indoor sources and activities on formaldehyde concentrations within the facility. The consistently lower outdoor concentration serves as a baseline, reinforcing the need to address indoor pollution sources.

The concentration of total volatile organic compounds (TVOCs) outside is consistently very low and remains stable throughout the measurement period. This stability indicates minimal variation in outdoor sources of TVOCs during the monitoring period, possibly due to fewer volatile organic compound emissions near the medical facility (Figure 3).

In contrast, the concentration of volatile organic compounds within the different rooms of the medical facility shows significant variability. This variability can be attributed to indoor activities and sources that emit these compounds. Specifically, in the treatment room and the doctor's office, the TVOC concentrations are notably higher. This level elevation is likely due to using and administering various medications and medical procedures that release volatile organic compounds. These activities include disinfectants, cleaning agents, and other chemical products commonly used in medical treatments and patient care.

This distinction between the stable, low outdoor concentrations and the variable, higher indoor concentrations highlight the impact of indoor sources on air quality within the medical facility.

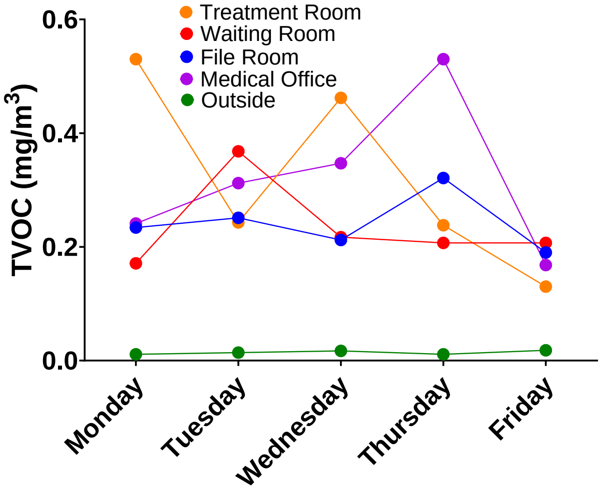


Figure 3. Daily variations in TVOC concentrations over one-week measurements in 4 rooms and outside.

It underscores the need for targeted air quality management practices, such as proper ventilation and low-emission products, to mitigate the impact of volatile organic compounds on indoor air quality and ensure a safe environment for patients and healthcare providers.

To decrease the levels of particulate matter and formaldehyde in the medical facility, a multifaceted approach is necessary. For particulate matter, enhancing the ventilation system by incorporating HEPA filters, increasing outdoor air intake, and using portable air purifiers can significantly reduce airborne particles. Wet cleaning techniques and regular maintenance of HVAC systems are essential to prevent the resuspension of settled dust and ensure efficient air circulation. Minimizing activities that generate particulate matter during peak occupancy times and safely storing materials that emit particulates can further mitigate exposure. For formaldehyde reduction, source control is critical, including replacing formaldehyde-emitting materials with low-emission alternatives and limiting the use of formaldehyde-containing products. Improved ventilation, particularly by increasing air exchange rates and installing dedicated exhaust systems in high-use areas, helps remove formaldehyde from indoor air. Additionally, the use of air purification technologies like activated carbon filters and photocatalytic oxidation systems can effectively lower formaldehyde concentrations.

CONCLUSIONS

This study highlights the critical need for effective air quality management in a small medical family doctor facility, where indoor pollutant levels, including particulate matter (PM_1, $PM_{2.5}$, PM_{10}), formaldehyde, and total volatile organic compounds (TVOCs), often exceed outdoor levels. Measurements showed that PM concentrations increased indoors throughout the week, particularly in the file room, waiting room, and treatment room, likely due to indoor activities and insufficient ventilation. Formaldehyde levels ranged from 21 to 100 µg/m³, peaking in the doctor's office on Thursdays and Fridays and mid-week in other rooms, indicating the impact of specific activities and materials such as the use of formaldehyde-containing disinfectants, and increased operation of office equipment like photocopiers and printers. While outdoor TVOC levels remained low and stable, indoor concentrations were highest in the treatment room and doctor's office, underscoring the need for targeted interventions to mitigate indoor pollution and ensure a safe environment for patients and healthcare providers.

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