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A review on optimization of process parameters of cold pressed oil extraction for high output and for enhanced quality and retained nutrients

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ABSTRACT

The purpose of this review is to explain cold pressed oil extraction and to analyze process parameters for maximum output, improved quality, and nutrient retention. Nowadays consumers are paying more attention in improving their health and quality of life.With modern lifestyle, human health and well-being are essential aspects of nutrition. When a seed is cold pressed, oil is extracted by applying force to the seed. Lower temperatures have little effect on the oil's characteristics, which include phenolic content, flavor, nutritional value, aroma, and taste. These oils are superior to refined oil in terms of nutritional value. The cold press method of production at low temperatures yields high quality oils. The cold pressed oils are healthier and more nutritionally balanced than refined oils, this process produces high-quality oils at low temperatures, and the process does not involve high heat or chemical processes. Cold press extracted oils primarily aim at their composition, nutritional quality, physicochemical characteristics, food applications, functional, oxidative stability, and health benefits. This review paper summarizes research on various methods of essential oil extraction for various raw materials, aiming to provide stakeholders in seed oil with useful insights for selecting the most suitable extraction methods.

1. Introduction

Today, consumers are increasingly seeking natural, healthy, and beneficial food products, and cold pressed oil is one of those options. In recent years, cold pressing has become the preferred method for extracting oil from oilseeds and fruits. This technique is user-friendly and often more cost-effective compared to other extraction methods. Cold pressed oils are obtained without the use of heat (generally temperature maintain during the process is below 50°C) or chemical treatment, which allows them to retain a higher concentration of beneficial bioactive compounds, including natural antioxidants, than refined oils. These bioactive components found in cold pressed oils include phytosterols, phospholipids, tocopherols, phenolic compounds, hydrocarbons pigments, as well as various flavor and aroma compounds. These minor fractions are crucial in determining the nutritional value and health benefits of edible oils (Konuşkan., 2020).

Milan and Vesna (2023), Studied the cold pressing oils obtained through cold pressing are unrefined and typically require only centrifugation or filtration to achieve high quality. This method preserves minor bioactive compounds that are often lost during the refining process. Various vegetable oils produced through cold pressing exhibit potential biomedical applications. this oil production technique is relatively simple and cost-effective compared to alternative methods. Cold pressed oils are derived from oil extraction processes that do not involve heat or chemical treatments, resulting in a higher retention of bioactive compounds, including natural antioxidants, compared to refined oils.

Cold pressed oils have the potential to protect as well as improve human health. In India, cold pressed oils are extracted from oilseeds like groundnut, soyabean, sunflower, sesame, safflower, coconut, mustard, castor, almond oil, flaxseed, rapeseed etc. which are pressed with steady and moderate pressure without any heat treatments to extract oil commonly referred to as virgin oil, these oils have become popular to consumers due to their organic, safe qualities as well as their ability to avoid certain diseases as well as improve human health. Raw materials quality is one of the most important quality aspects of oil made by cold

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pressing. (Wandhekar et al., 2022).

Most cold pressed oils have a higher nutritional content than refined oils, and contain higher amounts of naturally occurring nutrients, sterols and phospholipid (Gogolewski et al., 2000; Koski et al., 2003). The nutritional value of cold pressed oils is higher than that of refined oils. Cold pressed oils contain more naturally occurring ingredients (Koski et al., 2002; Górecka et al., 2003; Matthäus & Brühl, 2003). The significance of optimizing process parameters in cold pressed oil extraction cannot be overemphasized, as it promises to achieve high output, superior quality, and the retention of essential nutrients simultaneously. Nutritional value, colour, taste, aroma and quality to our favorite dishes, these oils are more useful than refined oils (Bartnikowska, 2007; Matthaus & Bruhl, 2008). The effects of functional foods on health needs to be well established by research studies.Cold pressing is the preferred method for both processors and consumers for extracting of oil due to its low production costs and retention of high bioactive ingredients, including essential fatty acids, carotenoids tocopherols, phenols, and phytosterols all these are only and only found in natural and pure oil (Parry et al., 2008). The methods of which impurities are removed from crude oils is known as "refining." refining to achieve an odorless liquid with improved stability of oxidative and a natural neutral taste (Luis et al., 2011). As per the Turkish Food Codex (2012), cold press oil is the oil obtained by mechanical means only for direct consumption without conducting any refining and chemical process.

The oil's quality is determined by the quality of the seeds utilized during the oil extraction process (Matthäus, 2013). The process of cold pressed oils producing mainly involves crushing seed using different methods, like expeller press to extract the oil, then sedimentation of the oil to remove any extremely small solid particles. Since fat is a great way for oil to carry taste and flavor, flaws in the raw materials. Therefore, selecting raw materials of a high quality is crucial because the cold press extraction process lacks different methods to improve the oil obtained was of high quality (Wroniak et al., 2015).

As per research conducted by Hasan et al. (2016), the oil samples were analyzed for various physical and chemical properties of various seeds. Three main systems are suitable for using to study cold pressing: twin-cold systems, expanders, and expellers. This method yields oil that is safe for human consumption and has ecological benefits. As a result, there is a greater need for cold pressed oils. It is imperative to guarantee that the oil extracted from cold presses is not hotter than 50°C. Physical techniques like sedimentation, centrifugation, and filtration also many steps are used to remove impurities from cold pressed oil without sacrificing its quality (Busra-Cakaloglu et al., 2018).Customers are starting to prefer cold press oils due to their distinct aroma, color, and potent flavor. Cold press oil is produced in an easy, environmentally responsible, and low-investment manner. However, it is very difficult to obtain what is being produced requirement and the oil produced out of raw materials is low Source (Matthäus and Brühl., 2003).

As per research by Lubna et al. (2022), cold press extraction is a hydraulic, energy-efficient, and environmentally friendly method for extracting oils without heat or solvents. Widely used across various sources, it produces high-quality oils at low temperatures. Consumers favor these oils for their natural, safe properties and health benefits, as they are rich in lipophilic phytochemicals like antioxidants, which help prevent diseases and support health. In a study, Alessandra et al. (2023) observed that the cold-pressing technology offers benefits like lower energy use and reduced investment costs. Compared to solvent extraction, it has a lower environmental impact and greater versatility, allowing for the quick and easy processing of various seed types.

Kachighani, commonly referred to as cold pressing, involves extracting oil from oil seeds through mechanical force. This technique utilizes a strong rotary device called the Ghani, which has been traditionally used in India for generations to extract fresh, natural, and pure cooking oil from various seeds such as sesame, peanut, coconut, sunflower, and more. The oil is processed at lower temperatures but retains its properties, such as high nutritional value, good taste, desirable flavor profile, and high phenolic content (Mohamed Fawzy Ramadan, 2020). It is important to note that many discrete attempts have been made theoretically to explore cold press extraction processes and their experimental validation to establish the combination of process parameters, specific quality indicators and sensitive compounds to improve the quality and yield of the oil. In case of cold extraction methods mostly, the processes are limited to the influence of various seed varieties on yield of oil extracted only. Thus, there is a comprehensive need to explore the physical and mathematical aspects associated with cold press extraction process.

This article reports the basics of oil extraction methods and influencing parameters, and several works carried out by multiple researchers to optimize process parameters involved in cold pressed oil extraction. The difficulties involved in cold pressed oil extraction, such as variations in raw materials, equipment restrictions, and the requirement to strike a balance between yield and quality have been reviewed. It also highlights emerging trends, advancements in technology, and future research directions in this field and also analyzes those different stages used for oil extraction.

2. Review methodology

Every researcher makes an effort to involve an analysis of the literature. In order to identify prospective research gaps that, if filled, could advance the subject of study, researchers can carefully review and analyze the appropriate literature. Saunders et al. (2016) recommended a methodological approach to literature review, which involves defining search keywords, conducting a thorough search, and conducting a detailed analysis. Following this guidance, in this study a similar review process has been implemented.

In this study, the first step was to identify key publications related to cold pressed extraction. To achieve this, papers from the science direct and google scholar database are reviewed, which is known for its vast collection of publications from reputed publishers like Springer, Science direct, Google scholar, IEEE, and Elsevier. The methodology of review process in this study adopted following procedure (Fig. 1).

2.1. Database selection

The process of database selection began with reviewing of articles from the available data sources. Google Scholar and Science Direct.com offer the greatest databases of abstracts and citations for a vast collection of academic and conference papers. It includes thousands of peer-reviewed articles in the social sciences, sciences, technology, and medicine. The journals are published by several publishing agencies including IEEE, Elsevier, Springer and others.

2.2. Selection of keywords

To establish a reliable, comprehensive and neutral search technique, the researchers cited the most reliable research articles on the topic. The author's use of terms that convey strong emotion and uphold a formal atmosphere might be classified as appropriate for a corporate audience. The writers employed the following categories keywords.

- **Keywords related to cold pressed extraction**

1. Method of cold pressed extraction
2. Cold pressed extraction equipment
3. Advantages of cold pressed extraction
4. Oils from cold pressed extraction
5. Research on cold pressed extraction

- **Keywords related to optimization**

1. Cold-pressed yield enhancement

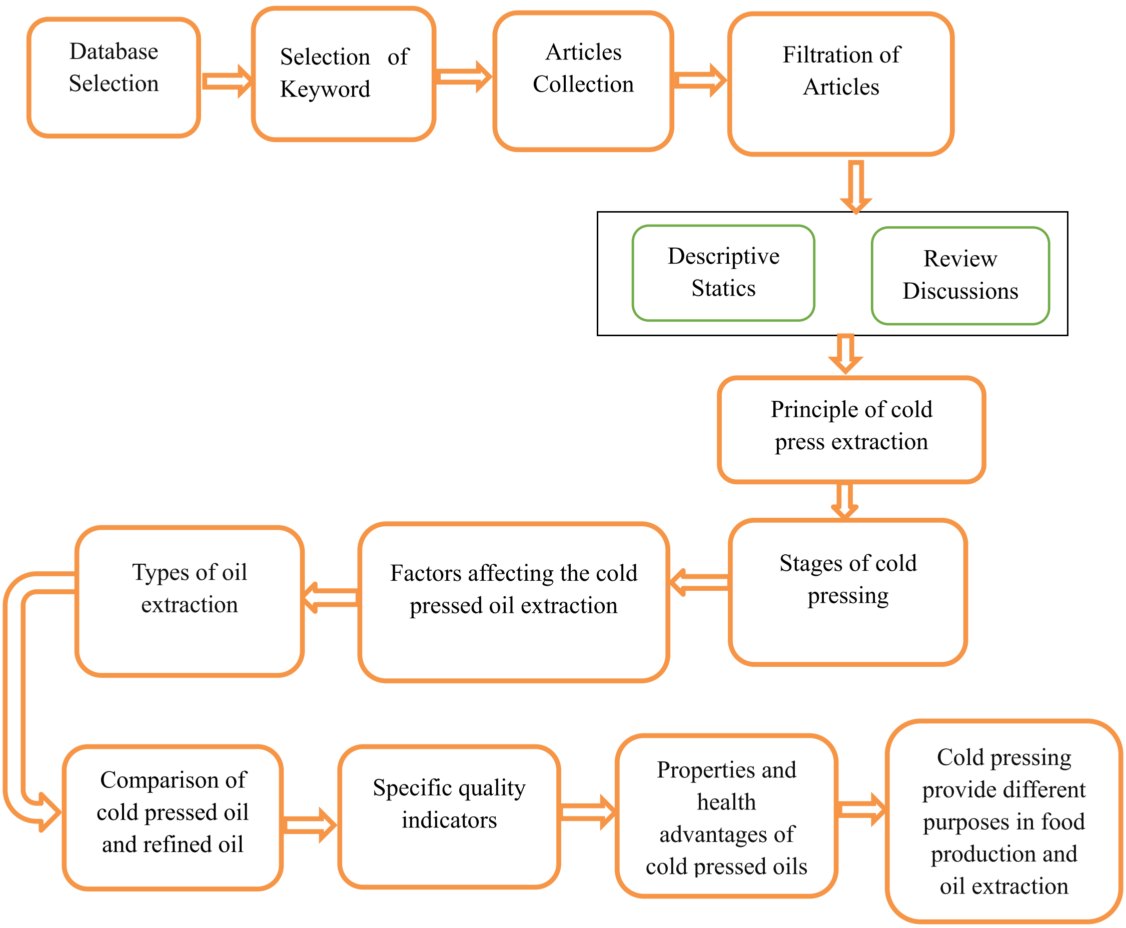

Fig. 1. The methodology employed for the systematic literature review.

2. Cold-pressed equipment optimization
3. Cold-pressed optimization of production
4. Strictly enforced quality control
5. Optimization of cold pressed extraction

2.3. *Articles collection*

The first set of terms were searched for a total of 342 article publications. In all 125 papers were refined from the initially selected set of total 342 published articles. It was ensured that all articles from book chapters, books, thesis, research papers, review articles, editorial notes etc. related to cold press extraction have been considered for review.

2.4. *Filtering the papers*

In order to enhance the precision of the findings, the authors

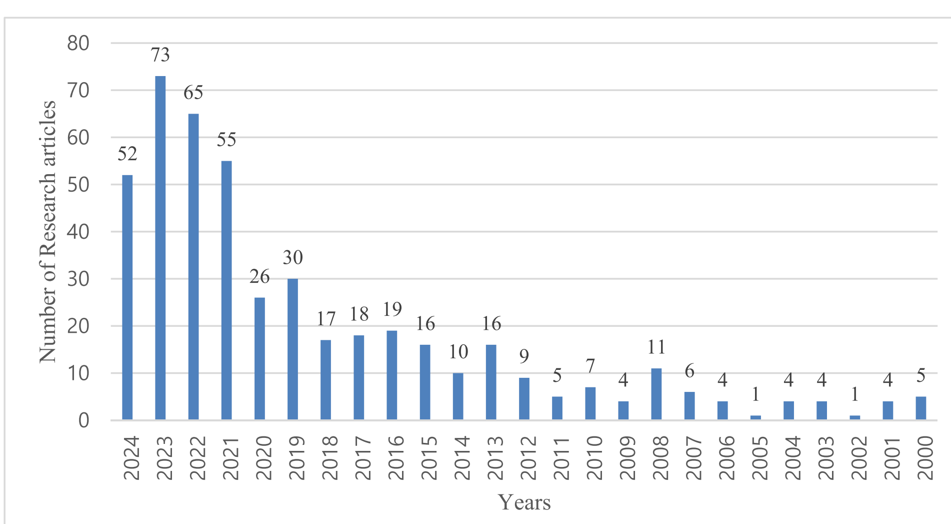

Fig. 2. Year wise Review article details.

eliminated duplicate papers that have been published in different keyword combinations and articles lacking complete bibliographic information.

3. Descriptive statistic

3.1. Year wise publications

There has been a significant increase in the number of publications in the optimization field of cold pressed oil extraction review between 2021 and 2023 (Fig. 2). On the other hand, the number of published review papers has dramatically increased since 2015. This demonstrates how academic interest in this new technology has grown since 2015.

3.2. Publication's titles

The most papers were published in Food Chemistry and followed in decreasing order by remaining publications (Fig. 3) including Review articles and Research articles. The data has been extracted from science direct.com.

3.3. Subject areas publication

The data has been extracted from science direct.com the maximum publications published subject area is agricultural and biological sciences and it follows remaining areas (Fig. 4).

3.4. Country wise contributions

After extracting the authors refereed total of 342 research articles from different nations, it was found that Poland topped the list with 28 of the 342 publications that were chosen. The following four countries on the list are Turkey, Iran, India, and the Netherlands, with contributions of 20, 21, and 25 papers each. This shows that Poland and Iran are the two countries which contribute the most to publications in research (Fig. 5).

4. Review discussions

The review discusses the optimization of process parameters for cold pressed oil extraction to achieve high output, enhanced quality, and retained nutrients. It likely covers various aspects such as temperature, pressure, extraction time, moisture content, and the impact of different raw materials on the extraction process.

Enhancing productivity and yield while maintaining the nutritional content and quality of the produced oil is probably the main goal. The difficulties involved in cold pressed oil extraction, such as variations in raw materials, equipment restrictions, and the requirement to strike a balance between yield and quality, will be covered in the review. It also highlights emerging trends, advancements in technology and future research directions in this field. And also analyze those different stages used for oil extraction.

5. Principle of cold press extraction

There are several procedures involved in extracting oil from oilseeds. Preparing the Raw Materials, cleaning, washing, drying the seeds, pressing mechanism, pressure application, oil separation, temperature control and quality preservation. Pressing and crushing are conducted using a pestle made of wood or stone, which is driven into a metal or steel mortar. The extracted oil is then filtered through muslin cloth. It is important to note that heat is not utilized at any stage of this procedure. Oils from a variety of seeds, nuts, and fruits can be extracted using a process called cold press extraction, frequently referred to as cold pressing or cold expeller pressing, which does not require the use of heat or chemical solvents. This process is preferred for producing high quality oils because it helps retain the natural flavor, color, nutrients and antioxidants present in the raw materials (Busra-Cakaloglu et al., 2018; Wandhekar et al., 2022).

6. Stages of cold pressing

6.1. Raw material preparation

The process of raw material preparation involves seed cleaning and washing to eliminate physical impurities like dust, dirt and adhered materials. In terms of safety handle seeds with gloves and masks, clean and dehull safely,control moisture, avoid dust explosions, ensure hygiene and allergen controls.

6.2. Seed conditioning

It is a process of adjusting moisture levels to achieve optimum moisture, which makes it easier to break down the cell and oil gland. This method improves the efficiency of oil extraction. The quality oils are determined by several factors including purity, consistency, integrity, and ripeness of the raw materials. The timing of harvesting, drying, storing, and managing oilseed crops after harvest also plays a crucial role in determining seed quality.

6.3. Seed crushing

The process of seed crushing, also called seed fragmentation, partially breaks down the seed's structure and shell, cracks open the

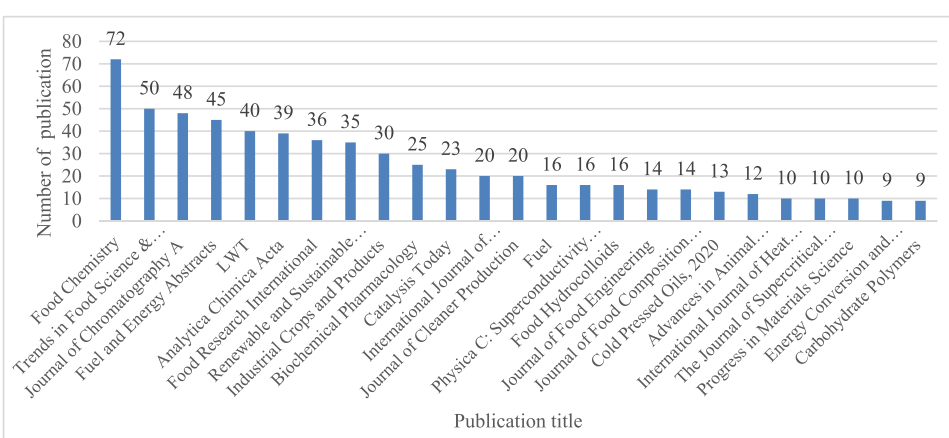

Fig. 3. Publications titles.

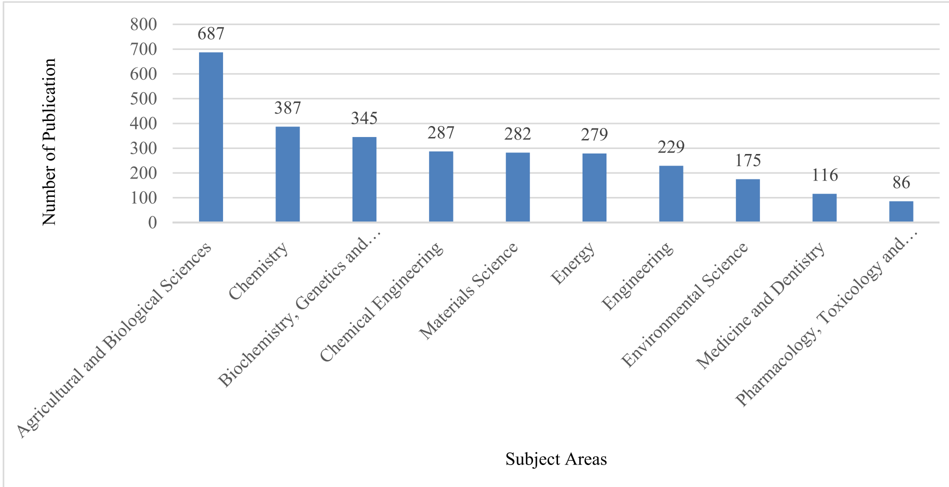

Fig. 4. Subject areas publication.

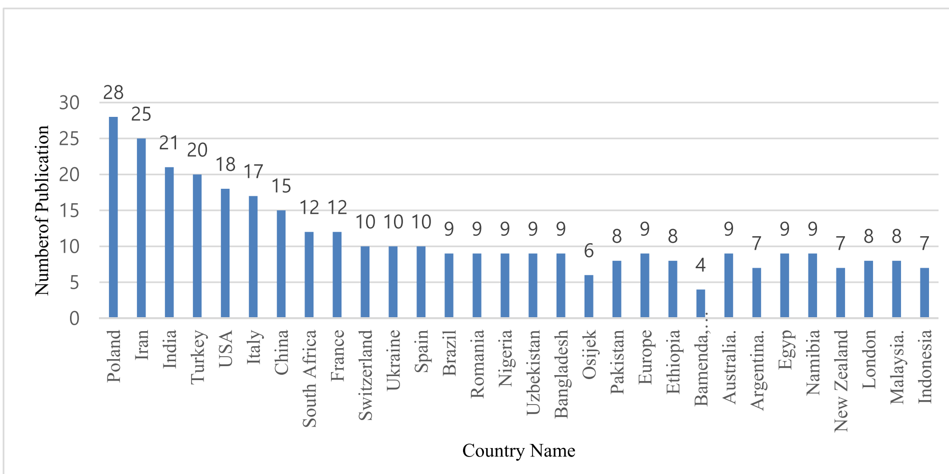

Fig. 5. Country wise research paper referred for review article.

cells, As the oil release area increases and the cell resistance decreases, it is thought that the quality of cold pressed oil increases due to timing. Therefore, it is necessary to press the crushed seeds, drain them, and collect the oil as quickly as possible.

6.4. Oil collection

Oil is obtained from oilseeds via crushing, gathered in a vessel for sedimentation, filtered, and then packaged in PET/glass bottles. To maintain a shelf life of several months, it is essential to store oils in lightproof, airtight, and moisture-proof containers in a cool setting.

7. Factors affecting the cold pressed oil extraction

Critical process parameters in cold pressed oil extraction include the type and quality of oil seeds, moisture content, storage of seeds, relative humidity, temperature, methods, oil content, feed rate, pressure, pressing time and packaging, These factors impact oil yield, nutrient retention and quality by controlling oil release while preventing nutrient degradation and maintaining flavor and purity. However, vitamins, and other nutrients remain intact in cold press extraction process.

7.1. Factors affecting the output and quality of oil

Natalia et al. (2022) studied the Soyabean, rapeseed, and sunflower oilseed cakes, especially from cold pressing, containing nutritional polyphenols that limit their use as protein sources. This study aimed to reduce polyphenols specifically sinapic and chlorogenic acids in canola and sunflower through pilot-scale extrusion without impacting protein quality. Extrusion increased the soluble-to- insoluble fiber ratio in canola (0.45–0.58) and sunflower (0.19–0.31) but reduced it in soybean (0.52–0.36). Canola and sunflower had high polyphenol levels, which reduced post extrusion, particularly in sunflower (by 68 %), while retaining protein solubility and quality, suggesting extrusion as a promising polyphenol reduction method. A variety of studies utilized response surface methodology (RSM) to methodically adjust these parameters. RSM, especially, facilitates the analysis of interactions between variables such as pressure and moisture content to better comprehend their collective impact on quality and yield. Shuzhen et al. (2022) examines how roasting and extraction methods impact rapeseed and flaxseed oil yields, sensory qualities, and chemical compositions. Rombaut et al. (2015) studied the effects of cold press extraction on the total phenolic content and yield of grape seed oil. Grape seeds from various harvest times were dried to 7 % moisture at 40°C, and Taguchi experimental design was used to assess the influence of factors like seed type, pre- heating temperature, rotational speed (20–110 rpm), and restriction die size (8, 10, 12, 15 mm). Oils were centrifuged at 3000 g for 10 min, and moisture, ash and phenolic content were analyzed. Results showed seed type as the key factor affecting phenolic, while higher moisture negatively impacted extraction performance despite optimized conditions.

Low temperature reduces the loss of mono unsaturated fatty acids (MUFA) and poly unsaturated fatty acids (PUFA) and also reduces the activity of seed enzymes and the extraction of unwanted compounds from the seeds into the oil (Sook, 2020; Bozdoğan, 2020). Although cold pressed oils have a high level of PUFA, it should be noted that PUFA oxidation is the main reaction that degrades the quality of the oil. Depending on the origin and type of oil, they are characterized by different oxidation stability, especially during thermal processing of food (Mildner-Szkudlarz et al., 2019; Ramesh et al., 2020; Różańska et al., 2019).

The researchers conducted experiments at different temperature settings (50, 100, and 150°C) and rotation speeds (20, 48 and 98 rpm). The research results indicated that when the temperature reaches 100° C and higher, the oil temperature decreases as the rotation speed increases. This trend might be attributed to reduced exposure time near the heating ring. Even with the heating ring set to 200 °C, the oil temperature remained below 84 °C, indicating that rotation speed played a critical role in temperature regulation. Along with various extraction techniques, the factors influencing the quality and quantity of fats (Juhaimi et al., 2018).

7.2. Factors affecting nutrient retention

Optimum pressure to ensure retained nutrients is possible by traditional optimum speed of 45–50 rpm. If its higher, all cell profile gets changed which affects nutrients to go in insoluble form. In cold pressed extraction process, oil is pressed from the pre-cleaned seeds under controlled temperature conditions, keeping the screw press temperature between 40°C to 50°C, to ensure all nutrients are intact. At higher temperature, cell profile changes and affects the nutrients. The variety of seeds are available but only few are suitable for providing good value nutrients for human consumption.

Singh et al. (2012), examined how different pre-treatment methods can affect the extraction efficiency of linseed oil when using cold press technology. Various pre-treatment techniques, including steam and enzyme treatments were used on certain linseeds, while others were left in their original state. The findings showed that pre-treatments had a notable impact on the amount of remaining oil and the rate of pressing, while they did not have a substantial effect on oil extraction and the amount of sediment. The analysis was conducted by Teh (2016) on the various factors influencing the oil extracted through the process of cold pressing from tomatoes, grapes and pomegranate seeds. The research investigated elements like initial heating conditions, particle dimensions, rotational speed in cold conditions, water content in seeds and the diameter of the dye used for restraint. It was noted that warming the seeds beforehand helped with extracting the oil and processing the seeds in their entirety led to the most successful oil extraction efficiency. Furthermore, it was discovered that reducing the speed at which the device rotates at low temperatures leads to better efficiency in oil performance because it allows for a longer period of contact. Research carried out by Rabadán et al. (2018) examines how cold press machine temperature affectsthe quality characteristics of different seeds. Moisture has the highest effect On quality and percentage of extraction of Mustard oil. Pre-treatment methods such as peeling and drying are essential due to the texture of the raw materials. Dominik et al. (2022) examined new oil blends with a balanced ω6/ω3 ratio (5:1), showing significant tocopherol loss and polar compound formation upon heating. Wheat germ oil blends retained greater nutritional stability. Divine et al. (2020) studied most seed oils are edible, while others serve as raw materials for soap, chocolate, margarine, biodiesel, and sustainable chemical production, requiring optimized extraction methods to enhance yield, quality, and efficiency.

7.3. Safety and health benefits of cold pressed oils

Cold pressed oils are extracted without heat or chemicals, preserving essential nutrients, antioxidants, and healthy fats. It provide a safer, healthier substitute by promoting immunity, improving digestion, lowering the risk of toxins, lowering inflammation, and improving heart health. The harmful effects of contaminants such as mycotoxins, pesticide residues, and heavy metals have been clearly documented through extensive research. Each of these substances, on its own, poses well-understood risks to human health. However, in reality, individuals are often exposed to a mixture of these contaminants through food and the environment. Assessing the combined or cumulative impact of simultaneous exposure to multiple toxins is highly complex. Interactions between different contaminants may amplify or alter their toxic effects. Despite scientific efforts, accurately determining the total health risks from such combined exposures remains challenging and is still not fully understood (Clarke et al., 2015; Pose-Juan et al., 2016; Eskola et al., 2019). Govindarajan et al. (2024) assessed the quality and safety of cold pressed vegetable oils from cottage industries in Tamil Nadu. 75 samples of coconut, groundnut, and sesame oils were analyzed, revealing 80 % non-compliance with Food Safety Standards, highlighting adulteration risks and the need for stricter enforcement. Dobrochna et al. (2023) Study carried out cold pressed oils have gained popularity for health benefits, retaining bioactive substances. Produced mechanically without heat treatment, Cold pressed oils are purified naturally, containing vitamins, minerals, and antioxidants linked to health, aligning with consumer preferences for less processed products.

8. Types of oil extraction

Oil extraction is the process of extracting oil from seeds, oil bearing plants and fruit with an oil content of more than 15 %. This traditional technique, which involves no solvents, is considered safe and is widely accepted in the industry. In the past, oil extraction was done manually using wooden pestles and bulls, but modern cold press mills equipped with hydraulic or screw-type expeller presses are now commonly used. This method is relatively straightforward and cost-effective (Busra-Cakaloglu et al., 2018). Some different important types of extraction are explained in the following:

8.1. Mechanical extraction methods

The conventional method for extracting oil involves mechanical extraction, where the seeds are enclosed by barriers that reduce the seed quantity. The seeds are pressed to extract the oil (Oniya et al., 2017). Oil obtained through mechanical extraction usually involves other parameters including its phosphorus value, iodine value, acid value, and water content, (Erna et al., 2015), The blessings of mechanical extraction consist of generating precise first-class oil and being capable of using its cake compared to extracting oil in solvents.

8.1.1. Kachi ghani

Kachi ghani oil evolved 5000 years back in india and was invented by the "Harappan Civilization". This is a traditional and ancient method of oil extraction initially oil extraction was done through the power of bull-driven oil ghani as depicted in Fig. 6. In modern days, bulls have been replaced by electric motor. In Cold pressing the temperature is below 50°C based on oil extracted from the seed. The ghani operated by bullocks can process a maximum of 10 kg of seed within a time frame of 2 hours. Motor-operated ghanis (Fig. 7) are more efficient than bullock-operated ghanis, the animals experience fatigue after continuously working for 3–4 hours. The average output of motor-driven ghanis is about 90 kg seed per day. The use of ghani for oil extraction is more advantageous because they do not need expensive machinery and seeds

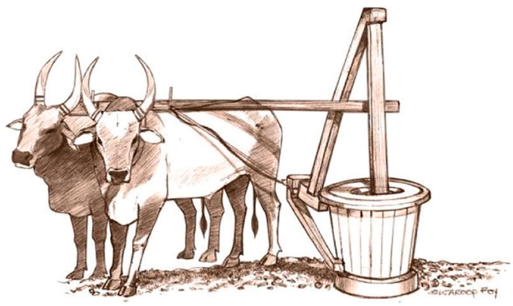

Fig. 6. Traditional method of oil extraction with bull.

Fig. 7. Cold press oil extraction machine.

not need any pre-treatment before extraction. Power ghani produces oil quantity double than bullock-operated ghanies for a typical power ghani setup (Head et al., 1995).

8.2. Solvent extraction process

In 1855, Deiss performed the first solvent extraction in France using carbon disulfide as the solvent. Hexane is frequently used as a solvent, despite the fact that many different solvents have been used over time (Kirschenbauer, 1944). Pradhan et al. (2010) used the cold press method, solvent extraction, and supercritical carbon dioxide extraction to analyze the chemical makeup of the oil extraacted from flax seeds. This indicates that the cold press method produced the lowest efficiency, supercritical CO_2 extraction came in second, and solvent extraction with hexane produced the highest oil yield. Examining the quality criteria, however, revealed that the cold press method produced oil of higher quality than the other methods.

The use of solvent extraction is decreased by the difficulty of extracting the solvent from the oil, the solvent's presence in the extracted oil, and the fact that it is environmentally detrimental. However, this process has a number of industrial disadvantages, including long extraction times, relatively high solvent consumption, high upfront costs, high energy demands, plant security issues, volatile organic compound emissions into the atmosphere, high operating costs, possible product quality compromises from high processing temperatures, and a relatively complex set of processing steps (Wang et al., 2011). Research indicates that the solvent extraction method yields 11.5 % more oil from low and medium fat seeds than the cold press method (Aguilera, 2003).

8.3. Hydraulic press

In 1785, J. Bramah first invented the hydraulic press for extracting oil from oilseeds. By the 1800s, advanced hydraulic presses equipped with 16 press boxes and capable of exerting 400 tons of pressure were in use (Kirschenbauer, 1944). Even though hydraulic press cages without filter cloth were very convenient in the 1900s, high efficiency was maintained in 1950 by techniques like solvent extraction and cold extractors that could be used in continuous systems. The hydraulic press and cold press methods for extracting palm oil were compared by Owolarafe et al. (2002). The oils produced using these two extraction techniques were compared in terms of yield and quality parameters, this suggests that the cold press extraction method is better than the extraction through hydraulic press since it requires less labor and money, produces more oil, and higher processing times. However, hydraulic extraction gives lesser yield as compared to cold pressed extraction and the quality is nearly same in both extraction methods.

9. Comparison of cold pressed oil and refined oil

Both virgin and refined vegetable oils are safe to eat, although virgin oils are becoming more and more popular as functional foods. Refining is the process of removing undesirable elements while preserving necessary ones. However, because of extreme circumstances like high temperatures and chemicals used in the refining process, it is occasionally impossible to prevent the formation of undesirable components and the removal of beneficial ones, which can have major negative health effects (Fataneh et al.,2022). The cold press technique usually maintains the nutritional value more effectively than alternative extraction methods, especially for compounds that are sensitive to heat, such as phenols, vitamins, and essential fatty acids. In contrast to extraction using solvents or expeller pressing, which typically require higher heat, cold pressing maintains temperatures below 50°C, thus avoiding the breakdown of nutrients. Research comparing cold pressing to other techniques, such as solvent extraction, has demonstrated that cold pressed oils usually contain greater amounts of antioxidants, vitamin E, and unsaturated fatty acids. Crude oil, derived from oilseeds through the use of high-pressure expellers and solvents like hexane and petroleum ether, is produced by applying heat. This process involves steaming the oilseeds at high temperatures, which leads to the breakdown of oil cells, the denaturation of proteins, and a decrease in oil viscosity. The dark color and high acidity of crude oil, which results from the high-temperature treatment, necessitate its refinement before it can be used. The refined crude oil undergoes several purification steps, including degumming, neutralization, bleaching, dewaxing, and deodorization. However, the high-temperature, high-pressure, and chemical refining processes can result in the loss of important bioactive components, such as carotenoids, tocopherols, and sterols. On the other hand, cold pressing oilseeds involve crushing them slowly to extract oil without the use of heat. This method preserves heat-sensitive bioactive components, as demonstrated by Busra-Cakaloglu et al. (2018). Conventional and green methods for extracting pomegranate seed oil, focusing on yield, properties, and nutritional compositions (Ning et al., 2022). Bertrand and Brühl (2001) evaluates oil content in rapeseed, sunflower, and soybean, analyzing tocopherols, diglycerides, and free fatty acids, with results aligning closely with the German Fat Science Society standard method. Małgorzata et al. (2008) study carried out cold pressed and virgin rapeseed oils (heated seeds) produced in the lab, comparing them with industrial hot-pressed, crude, bleached, and deodorized oils. The extraction method did not alter fatty acid composition, typical of low-erucic rapeseed, with trans fatty acid isomers only found in fully refined, deodorized oils (1.1 %). Cold-pressed oils displayed superior quality, particularly in color, acid and peroxide values, and Totox, though slightly less stable in Rancimat tests (5.08 h vs. 5.37 h for fully refined oils). Cold pressed oils retained 25 % more tocopherols and lacked trans isomers, supporting their nutritional advantage so there is a several studies have compared the nutrient retention content in cold pressed oils sensitive compounds like phenols, vitamins, and essential fatty acids. Sangram et al. (2023) studied that Refined oil and cold pressed oil in Crude oil is extracted from oilseeds using heat, pressure, and solvents like hexane, breaking oil cells and lowering viscosity. The dark, acidic oil requires refining, which may reduce bioactive compounds. Cold pressing, by contrast, gently crushes seeds without heat, preserving sensitive nutrients like carotenoids, tocopherols, and sterols.

10. Specific quality indicators

Specific quality indicators of cold pressed extraction help maintain oil freshness, stability, and nutritional value.

10.1. Phenolic content

Phenolic compounds, which are important for their antioxidant properties, tend to degrade with heat and solvent exposure. Cold pressing typically preserves higher levels of phenols compared to solvent extraction. Studies on olive oil (Boskou et al., 2005) have shown that cold pressed olive oils retain significantly higher levels of phenols compared to oils obtained using heat or solvents. Phenolic compounds are responsible for lipids nutritional and organoleptic properties. Moreover, phenols can prevent oil deterioration, through quenching of radicals present in reactions of lipid oxidation. Maqsood et al. (2014) studied those rapeseed oils total phenolic were measured in oil's methanol extracts. While synthetic antioxidants have been used, health concerns have shifted attention to natural alternatives. Plant-derived polyphenols effectively inhibit lipid oxidation in fish muscle, oil, and emulsions. This review highlights the sources and roles of these phenolic antioxidants in preserving seafood quality. Additionally, polyphenols can act as anti-inflammatory, anticancer, and antibacterial agents. Consequently, phenolic compounds help inhibit oxidation reactions in oils, impacting both their sensory qualities and nutritional value. Cold pressed oils are particularly rich in phenolic compounds, as these are retained due to the absence of a refining process (Grajzer et al., 2020a, 2020b; Sánchez-Arévalo et al., 2020; Symoniuk et al., 2017). The increasing consumption of cold pressed oils (CPOs) is due to their beneficial compounds like PUFA, tocopherols, sterols, and polyphenols. This study evaluates and compares the fatty acid composition, antioxidant activity, and oxidative stability of six popular Polish CPOs, including linseed, pumpkin and sunflower oils. Dobrochna et al. (2023), Yao et al. (2022) studied that numerous phenolic compounds play a role in oilseed growth, control the oxidative stability of the corresponding vegetable oil and are significant minor food ingredients that have positive health effects. The distribution of phenolic compounds composition varied among oilseeds. The primary phenolic compounds found in soyabean, rapeseed, peanut skin, olive, sunflower seed, sesame and flaxseed were isoflavones, derivatives of sinapic acid, epicatechin and catechin, phenolic alcohols, chlorogenic acid and lignin, in that order. Therefore, more research is required on the simultaneous extraction of free, conjugated and bound phenolic compounds. Table 1. provides a summary of the most recent extraction and analytical techniques for phenolic compounds found in oilseeds.

10.2. Vitamins

Cold pressed oils are rich in vitamins, particularly fat-soluble

Table 1
Extraction and analytical methods of phenolic compounds in oilseeds and their products (Yao et al., 2022).

Source	Phenoliccompounds	Extraction method	Determination method	Quantitative Value (mg/ 100 g)	References
Sesame,peanut,rapeseedmeal	TPC, TFC, TTC	UAE,SLE (acetone,ethanol, methanol)	Spectrophotometer	20–50	(Chen et al. 2020,Zhang et al. 2019, Yang et al. 2020)
Sesame,sunflower meal, flaxseed capsule,rapeseed, rapeseedmeal andrapeseedoil	Phenoliccompounds, lignans	UAE,SLE,LLE (acetonedistilledwater, methanol)	HPLC-PDA, UPLC	10–35	(Wang et al., 2021, Chen et al. 2020,Wang et al. 2020), Slabi et al. (2019))
Virginoliveoil,rapeseed, walnut kernel,rapeseedoil	Phenoliccompounds	LLME,LLE,SLE,SPE, QuEChERS (methanol, ethylacetate)	UHPLC-ESI-MS/MS, LC-MS/MS, UPLC-MS/MS	5–20	(Yu et al. 2021,Wang et al. 2021,Wu et al. 2021,Miho et al. 2021,Becerra-Herrera et al. 2014, Song et al. 2019)
Sesame	Phenoliccompounds	SLE (methanol)	HPLC-QqQ-MS/MS	5–15	(Wang et al. 2018)
Rapeseedandrapeseedoil, soybean,peanut,olivemill pomaceandwastewater	Phenoliccompounds, isoflavoneaglycones	SLE,LLE, Microwave-assistedacid hydrolysis (methanol,ethanol, ethyl acetate)	UPLC-ESI-QTOF-MS/MS, UHPLC-ESI-QTOF-MS/MS, UPLC-QTOF-MS, HPLC-ESI-QTOF-MS	10–30	(Cong et al. 2020,Kim et al. 2020,Višnjevec et al. 2021, Yang et al., 2020)
Soybean seed coat,peanut	Phenoliccompounds	Soxhletextraction,UAE (ethanol,acetone)	HPLC-Q-Orbitrap-MS/MS, LC-ESI-Orbitrap-MS	8–25	(Chen et al. 2020, Juliano et al. 2020)
Peanutby-product	Phenolicacidsandflavonoids	SLE (acetone)	HPLC-ESI-MS^n	Not specified	(Camargo et al. 2017)
Peanutshell	Luteolin	$dTi_3C_2T_x$/MWCNTs	Electrochemicalsensingplatform	Not specified	(Liu et al. 2022)

TPC, total phenolic content; TFC, total flavonoid content; TTC, total tannin content; UAE, Ultrasound-assisted extraction; SLE, solid-liquid extraction; LLE, liquid-liquid extraction;LLME,liquid-liquid micro extraction; SPE, solid-phase extraction; QuEChERS, Quick-Easy-Cheap-Effective-Rugged-Safe method; d-$Ti_3C_2T_x$/MWCNTs, titanium carbide/multi-walled carbon nanotubes; HPLC-PDA, high-performance liquid chromatography-photodiode array; UPLC, ultra-performance liquid chromatography; UHPLC-ESI-MS/MS, ultra-highpressure liquid chromatography-electrospray ionization-tandem mass spectrometry; LC-MS/MS, liquid chromatography-tandem mass spectrometry; UPLC-MS/MS, ultra-performanceliquid chromatography-tandem mass spectrometry; HPLC-QqQ-MS/MS, high-performance liquid chromatography-triple quadrupole-tandem mass spectrometry; UPLC-ESI-QTOF-MS/MS,ultra-performance liquid chromatography-electrospray ionization-quadrupoletime off light tandemmasss pectrometry; UHPLC-ESI-QTOF-MS/MS,ultrahigh pressure liquid chromatography-electrospray ionization-quadrupoletimeofflight tandemmassspectrometry;UPLC-QTOF-MS, ultra-performance liquid chromatography-quadrupoletimeofflight-mass spectrometry; HPLC-ESI-QTOF-MS, high-performance liquid chromatography-electrospray ionization-quadrupole time of flight-massspectrometry; HPLC-Q-Orbitrap-MS/MS, high-performance liquid chromatography-quadrupole-orbitrap-tandem mass spectrometry; LC-ESI-Orbitrap-MS, liquid chromatography-electrospray ionization-orbitrap-massspectrometry; HPLC-ESI-MS^n, high-performance liquid chromatography-electrospray ionization-multistage mass spectrometry.

vitamins. Vitamin-E-active substances like tocopherols and tocotrienols are crucial trace elements that give the oil its antioxidant properties and oxidative stability. These vitamins provide antioxidant benefits, support immune function and promote skin health. The cold pressing process preserves these nutrients, making oils like olive, sunflower, and flaxseed valuable sources of essential vitamins for overall health.

10.3. Fatty acids

Fatty acids such as omega-3 and omega-6, are also more stable in cold pressed oils. High-value minor lipid compounds show health promoting characteristics and have a positive impact on our body's biological processes (Ibrahim et al. 2017; Kiralan et al., 2017). Exposure to heat and certain solvents in other extraction methods can cause oxidative degradation, reducing their nutritional quality. Fatty acid profiles have been widely used to assess the quality of CPOs, particularly to determine their real thing.

10.4. Flavor profile

The flavor profile of cold pressed oils includes aroma, taste, mouthfeel, and aftertaste, highlighting each oil's unique sensory qualities. Typically assessed by trained panels, key attributes signal high quality. Advanced methods like GC-MS identify flavor compounds. Balanced, fresh flavors indicate quality, while off-flavors (rancidity, sourness) suggest oxidation or poor processing.

10.5. Oxidative stability

Cold pressed oils generally have lower oxidative stability than refined oils due to their natural impurities and higher unsaturated fatty acid content (Eunok & Min, 2006; Redondo-Cuevas et al., 2018). Factors contributing most significantly to oxidative stability during processing and storage include fatty acid composition, antioxidant levels and exposure to light, oxygen, and temperature. Refined oils, processed with antioxidants, exhibit better oxidative stability.The oxidative stability of oil is an important quality and safety parameter for its potential commercial applications and its uses in food and other commercial products. Oxidative stability depends mostly on the FA composition, as well as on the potency and concentration of the antioxidants in the oil (Parker et al. 2006). The author characterized antioxidant activity and oxidative stability of various cold-pressed oils, analyzing radical scavenging, fatty acids, and oxidative stability, finding correlations between DPPH activity and oxidation product formation (Anna et al., 2014). Dedebas et al. (2020) studied the storage stabilities, chemical characteristics, and bioactivity of cold pressed seed oils, revealing temperature and time significantly affect oxidative deterioration and shelf life. One of the most crucial factors defining oil's oxidation susceptibility is its oxidative stability, which is linked to its shelf life. Using the Rancimat method, the oxidative stability of the CPOs under study was ascertained and represented as the induction period (IP) at 100° C. Oxidative stability in oils, key to maintaining quality, depends on fatty acid composition, antioxidants, pro-oxidants, processing, and storage. Oils with polyunsaturated fats oxidize faster, while antioxidants like tocopherols enhance stability. Cold-pressed oils retain these nutrients but need careful storage, light, oxygen, and temperature have a significant impact on oil stability over time. Storing oils in dark, airtight containers in a cool environment minimizes exposure to these factors, thereby slowing oxidation.

10.6. Cold press of seed blends

Cold pressing of seed blends involves mechanically extracting oil without heat or chemicals, preserving nutrients and flavor. Blending seeds enhances oil quality, alters fatty acid profiles, and increases stability, making it a healthier extraction method.and more sustainable. As per research conducted by Yeganeh et al. (2019), Oil seeds are typically pressed individually to extract the oil, but this study explored blends of black cumin seed (BS) and sunflower seed (SS) for cold pressing. Blending altered the fatty acid profile, increased total pigments and phenolic content, and enhanced oxidative stability from 6.78 to 9.69 hours. The findings recommend blending oilseeds before cold pressing to improve oil quality and stability. Zeinab et al. (2022) study carried out Co-extraction of pomegranate seed oil (PSO) with green tea leaves (GTL) (0–10 % w/w) using cold pressing was evaluated for oil quality during storage. Extraction yield was comparable to the control sample up to 5 % GTL, which also increased phenol and chlorophyll content. Oils with 5 % GTL exhibited the lowest acid and peroxide values and the highest oxidative stability (11.5 h), offering a cost-effective, chemical-free method.

Flaxseed oil, rich in α-linolenic acid (an ω3 fatty acid), is prone to oxidation. To enhance oxidative stability, olive leaves (0–10 % w/w) were added during cold-press extraction. Blanched leaves significantly increased carotenoids, chlorophylls, phenolic content, and oxidative stability (11.4 h vs. 7.2 h control) while preserving polyunsaturated fatty acids. Unblanched leaves raised acid values, whereas blanched leaves delayed oxidation effectively. Incorporating up to 7.5 % blanched olive leaves produced oils with high bioactive content and improved stability (Ramin et al., 2024).

Black cumin (Nigella sativa) seed (BS) oil typically has high peroxide (PV) and acid values (AV). In this study, BS was treated with rosemary extract as a natural antioxidant before and after microwave pretreatment. Optimum conditions included 120 seconds of microwave radiation followed by 4 % rosemary extract, resulting in lower PV (8.4 meq O_2/kg) and AV (3.2 mg KOH/g), while increasing chlorophyll, carotenoids, polyphenols, thymoquinone, and tocopherol content. Pretreated BS oil showed improved bioactive components, stability, and reduced oxidation compared to the control (Ashrafi et al., 2023)

11. Chemical compounds in cold pressed oil

Cold pressed oils contain a variety of beneficial chemical compounds that contribute to their nutritional and health promoting properties. Rękas et al. (2016), study carried out compares the quality parameters and chemical composition of cold-pressed oils from six rapeseed varieties, revealing correlations between fatty acid composition, oxidative stability, and tocopherol content variations. Devanesan et al. (2018), studied cold press extraction preserves essential phytonutrients from oil seeds, unlike chemical and hot press methods, which degrade quality. The study examines six cold-pressed oils' antioxidant and nutrient profiles (sesame, coconut, peanut, neem, castor and iluppai) were determined. Fernanda et al. (2018) studied Grape seed oil, a by-product of winemaking, is gaining attention for its potential as a vegetable oil alternative. This study analyzed Brazilian Grape seed oil chemical composition, antioxidant activity, and phytochemical content. Costa et al. (2019) analyzed the chemical composition of three commercial pomegranate seed oils (PSO) from Turkey and Israel, focusing on fatty acids, lipid classes, volatile compounds, quality indices, oxidative stability, and bioactive compounds. Results showed similar quality and lipid classes, with higher conjugated linolenic acid in PSO from Israel.

12. Phytosterols in cold pressed oils

Sterols are a group of naturally occurring compounds found in plant-based oils, known for their cholesterol lowering properties and health benefits. Sterols, with over 250 distinct structures, typically occur in concentrations of 0.4–1000 mg/100 g oil, with varying ratios among them. This study developed a gas chromatography-mass spectrometry (GC/MS) method to quantify 30 sterols, despite only ten having reference standards. This improved method enables better detection and quantification of sterols in vegetable oils, aiding food authentication (Sarah & Vetter, 2023).

In cold-pressed oils, sterols contribute to the overall nutritional profile and stability of the oil.The sterol compositions and total sterol contents (TSC) of the six investigated oils are presented.The sterol profiles of the tested cold-pressed oils (CPOs) may be influenced by various factors, including different cultivars, as well as growing, processing, and storage conditions (Dobrochna et al., 2023).

13. Oxidation process and storage conditions in cold pressed oils

Oxidation is a chemical reaction that occurs when oils are exposed to oxygen, leading to the degradation of fatty acids and the formation of harmful compounds. In cold pressed oils, which are rich in unsaturated fatty acids, oxidation can significantly affect their quality, safety, and nutritional value. During the shelf life of cold pressed oils, the oxidative stability parameters remain within the established limits, even if oxidative processes occur (Vujasinovic et al., 2010). Oil damage during storage, leading to reduced quality and yield, may result from deterioration, contamination, or deliberate adulteration (Gary et al., 2005). Compromise the stability of oils when stored in home settings, where they may be exposed to light, left open come into contact with air, or maintained at room temperature (Martínez et al., 2011). Cold pressed hempseed oil (HO) is nutritious but prone to oxidation due to its high PUFA content. This study found that filtered HO (F-HO) has better oxidative stability and retains antioxidants better than non-filtered HO, making it more suitable for storage. Vincenzo Lo Turco (2023). The study analyzed various cold pressed oils to identify volatile compounds as oxidation markers, using accelerated storage tests and multivariate analysis to differentiate oils by plant variety and oxidation levels (Anna et al., 2021). The study evaluated the antioxidant activity and oxidative stability of various cold-pressed oils using the DPPH assay. Trolox equivalent antioxidant capacity (TEAC) ranged from 0.17 to 2.32 mM, with higher activity in lipophilic fractions. Fatty acid composition remained stable during shelf life (Prescha et al., 2014). As per research conducted by Sean et al. (2015). Human societies have developed storage and transportation methods to combat food fluctuations, evolving from low energy techniques to energy intensive systems, raising challenges as fossil fuel supplies diminish. Stored vegetable oils, like rapeseed oil, are prone to oxidation, hydrolysis, and thermal polymerization, leading to quality deterioration. This study analyzes how storage temperature, packaging type, and oxygen-free conditions affect the chlorophyll and carotenoid content, color, acid value, and antioxidant activity over three and six months. PCA identified key factors influencing quality changes (Damian et al., 2023).

Based on the chosen Appl. Sci. 2023, 13, 11746 5 of 10 parameters over the 3- and 6-month oil storage periods, the results obtained using the methodology described were averaged and transformed into percentage changes with regard to the control sample. (Table 2) displays all of the test results for every oil sample. The results indicated that the chlorophyll and carotenoid content in cold pressed rapeseed oil decreased over time. After three months, natural dye levels dropped by 7–87 %, and after six months, by 12–97 %. This reduction was primarily influenced by the storage temperature of the samples.

14. Adulteration in cold pressed oils

Adulteration is beyond the scope of cold pressed and wood pressed oils, as these processes do not involve any adulteration. However, if it does occur, it can be detected using the techniques described in Table 3. Azadmard-Damirchi and Torbati (2015) study carried out high-cost oils like olive oil and cocoa butter are often adulterated for profit. Sophisticated adulteration methods now demand advanced detection techniques. This review highlights the need for effective methods to ensure authenticity, protect industry standards, and assure consumers of oil purity. Huq et al. (2022) discussed the concerns about the purity of fats and oils, essential for food and cooking, have existed throughout history. With rising adulteration rates globally, this study reviews rapid detection techniques for ensuring food quality and safety. It summarizes methods for consumers to check for adulteration, such as the use of argemone oil in mustard oil. LOD (Limit of Detection) indicates the smallest detectable amount and LOQ (Limit of Quantification) is the minimum quantifiable concentration same as Linear range specifies the concentration range where detection remains proportional to concentration.

15. Consumer demand

There is strong demand for cold pressed (ghani) oil, as it retains the natural flavor and beneficial properties of the oil seeds, unlike expeller-extracted oils. Consumers prefer it for its unique qualities, especially in pickle production and other specialty products. Globally, consumers are increasingly choosing cold pressed oils for their nutrient content and health benefits. Valued at USD 30.8 billion in 2024, the market is projected to grow at a CAGR of 5.2 % from 2025 to 2030, driven by a preference for natural, minimally processed foods free of chemical

Table 2
Percentage (%) changes in rapeseed oil parameters during storage.

Sample	Chlorophyll	Carotenoids	L*	a*	b*	AV	ABTS
PET, 3 months, N_2, 25 ∘C	−7.04	−6.14	−0.52	20.46	3.37	123.06	57.06
PET, 3 months, N2, 4 ∘C	*−7.04*	*−6.68*	*−2.57*	40.1	3.29	59.87	27.68
PET, 3 months, Air, 4 ∘C	−7.04	−3.25	−2.80	31.19	2.82	67.02	49.72
PET, 6 months, N2, 25 ∘C	−81.69	−13.72	−2.66	35.12	5.74	167.29	106.21
PET, 6 months, N2, 4 ∘C	−12.68	−7.22	−2.96	60.58	4.94	89.81	77.97
PET, 6 months, Air, 25 ∘C	−83.10	−12.27	−2.62	51.68	4.27	221.36	119.77
PET, 6 months, Air, 4 ∘C	−12.68	−8.48	−3.31	52.42	4.39	102.41	70.06
Clear glass, 3 months, N2, 25∘ C	−87.32	−7.04	−1.58	24.15	2.31	125.29	50.85
Clear glass, 3 months, N2, 4 C	−8.45	−6.32	−2.53	31.59	4.68	50.09	29.38
Clear glass, 3 months, Air, 25 ∘C	−69.01	−22.38	−1.08	20.92	2.35	160.41	62.15
Clear glass, 3 months, Air, 4 ∘C	−19.72	−4.87	−2.65	35.66	3.84	71.58	53.11
Clear glass, 6 months, N2, 25 ∘C	−97.18	−12.09	−2.70	40.28	2.03	155.85	98.31
Clear glass, 6 months, N2, 4 ∘C	−21.13	−7.22	−3.03	51.11	4.85	103.31	85.31
Clear glass, 6 months, Air, 25 ∘C	−95.77	−35.38	−3.23	65.43	2.34	218.23	110.17
Clear glass, 6 months, Air, 4 ∘C	−21.13	−5.96	−2.92	48.91	3.85	108.04	66.1
Colored glass, 3 months, N2, 25 ∘C	−21.13	−16.25	−0.39	8.9	1.58	93.66	36.16
Colored glass, 3 months, N2, 4 ∘C	−12.68	−3.07	−1.25	23.58	2.79	27.52	11.86
Colored glass, 3 months, Air, 25 ∘C	−30.99	−17.69	−0.98	8.44	3.53	127.44	44.63
Colored glass, 3 months, Air, 4 ∘C	−4.23	−7.40	−1.22	28.23	2.43	66.31	39.55
Colored glass, 6 months, N2, 25 ∘C	−57.75	−17.15	−1.89	33.7	3.53	140.57	85.88
Colored glass, 6 months, N2, 4 ∘C	−14.08	−7.04	−2.86	60.77	3.65	71.76	71.19
Colored glass, 6 months, Air, 25 ∘C	−45.07	−28.70	−2.41	65.43	4.69	184.09	98.87
Colored glass, 6 months, Air, 4 ∘C	−15.49	−13.36	−2.00	48.91	3.63	81.05	50.85

Table 3
Rapid detection techniques of fats and oils adulterations (Huq et al. 2022).

Food Article	Adulterants	Detection ways of adulteration	LOD (mg/kg or μg/L)	LOQ (mg/kg or μg/L)	Linear Range (mg/kg or μg/L)	References
Mustard oil	Super soybean oil	By detecting separate colors with the help of a HCL-based kit.	0.1 mg/kg	0.2 mg/kg	0.2–10 mg/kg	Supriya (2020)
	Cotton seed oil	By observing a red coloration after heating with amyl alcohol.	0.05 mg/kg	0.1 mg/kg	0.1–5 mg/kg	FSSAI (2012)
	Argemone Oil	By seeing a red color after adding nitric acid in the sample.	0.2 mg/kg	0.5 mg/kg	0.5–15 mg/kg	Abhirami and Radha -(2015)
Soybean oil	Palm oil	Separate layer of color will be observed after gentle shake in a nitric acid based kit.	0.1 mg/kg	0.3 mg/kg	0.3–8 mg/kg	FSSAI (2012)
Edible oil	Prohibited color	A layer of color will be observed after adding and shaking the sample with HCL	0.01 μg/L	0.05 μg/L	0.05–2 μg/L	FSSAI (2012)
	Rancidity	The appearance of white color turbidity with the help of ammonium molybdate reagent	0.005 mg/kg	0.01 mg/kg	0.01–5 mg/kg	FSSAI (2012)
Coconut oil	Any oil	Sample of oil will get solidified after refrigerating leaving a separate layer of adulterant	0.1 mg/kg	0.3 mg/kg	0.3–12 mg/kg	FSSAI (2012)
	Cyanide	Presence of blue color in the sample after addition of alcoholic potash, ferrus sulphate and ferric chloride consecutively.	0.001 μg/L	0.005 μg/L	0.005–0.5 μg/L	FSSAI (2012)
Olive oil	Vegetable oil	Detected by conventional methods at below 5 % adulteration level	0.05 mg/kg	0.1 mg/kg	0.1–10 mg/kg	Christopoulou et al. (2004)
Rice bran oil	Any other oil	By observing an orange color of 5-phenylazo-γ -oryzanol or 5- phenylazoferulic acid when sample oil is treated with benzenediazonium chloride solution at 0–5°C	0.1 mg/kg	0.25 mg/kg	0.25–15 mg/kg	Ulberth and Buchgraber (2003)
Sunflower oil	Palm oil, castor oil and Paraffin	Using colorimeter	0.005 mg/kg	0.01 mg/kg	0.01–3 mg/kg	Abhirami and Radha (2015)
	Castor Oil	By the addition of 10 mL petroleum to the sample oil and observing the white turbidity	0.02 mg/kg	0.05 mg/kg	0.05–10 mg/kg	Abhirami and Radha (2015)
	Argemone oil	A layer of red-brown color will indicate adulteration with argemone oil when mixed with nitric acid.	0.2 mg/kg	0.5 mg/kg	0.5–15 mg/kg	FSSAI (2012)
	Mineral oil	Heating with alcoholic potash and the presence of turbidity will indicate adulteration with mineral oil.	0.01 mg/kg	0.03 mg/kg	0.03–10 mg/kg	FSSAI (2012)
	Vanaspati	The presence of vanaspati will be detected by shaking the sample with furfural solution	0.05 mg/kg	0.1 mg/kg	0.1–10 mg/kg	FSSAI (2012)
Vegetable oil/ Gingerly oil	Castor oil	Formulation of turbidity might be observed after adding ammonium molybdate reagent	0.02 mg/kg	0.05 mg/kg	0.05–5 mg/kg	FSSAI (2012)
	Argemone oil	Yellow, orange or crimson color layer will indicate adulteration after adding HNO3	0.2 mg/kg	0.5 mg/kg	0.5–15 mg/kg	Abhirami and Radha (2015)
	Mineral oil	The appearance of turbidity after addition of alcoholic potash and 10 mL of water.	0.01 mg/kg	0.03 mg/kg	0.03–10 mg/kg	Abhirami and Radha (2015)

additives. Suchitra et al. (2022) study carried out cold pressed oil extraction involves using controlled temperatures to extract oil from seeds like sesame, olive, and coconut. This method preserves taste, color, and nutrition without chemicals or preservatives, making it healthier and eco-friendly. However, challenges like low oil yield and high residual oil need addressing. The aims to provide cost estimations to support efficient planning and investment for cold-press oil extraction units. Srujana et al. (2021) studied in natural and organic foods, particularly oils, has surged in recent years. Cold pressed oils, extracted from oilseeds, are significant in cosmetics, medicine, and cooking. A study in Hyderabad, Telangana, surveyed 90 randomly selected consumers to assess their awareness, preferences, and purchasing behavior regarding cold-pressed oils. Results showed low awareness, with health benefits and price being key factors influencing purchasing decisions.

16. Methods of optimization for vegetable oil extraction

Numerous optimization techniques involve the utilization of statistical software to enhance control variables such as extraction time, sample weight, solvent volume, solvent type, seed variability, and particle size, among others. The objective is to reduce costs and improve performance while simultaneously minimizing any potential decline in product quality (Yenge Govind et al. 2017). The oil extraction, the literature identifies two primary methods for process optimization: the traditional or conventional optimization method, which alters one variable at a time often referred to as single parameter optimization and the design of experiments (DOE) approach, which allows for the simultaneous variation of multiple variables to account for interactions among the factors (Masime, et al., 2017).

17. Properties and health advantages of cold pressed oils

Cold pressed oils, obtained by mechanical extraction at minimum temperatures without the need for heat or chemicals, exhibit a range of distinctive characteristics that set them apart from oils extracted using alternative techniques. Famous for their exceptional quality, nutritional benefits, and untainted purity, cold pressed oils have become a favored option among individuals who prioritize their well- being.

1. Cold pressed oil retains the majority of the proteins, phospholipids, nutritional integrity vitamins, antioxidants, and lecithin while having a high phenolic acid content.
2. The best cold pressed oils maintain their original flavor, aroma, and antioxidant qualities, making them excellent for both skincare and cooking purposes. Antioxidants help to defend against tumors and infections (Busra-Cakaloglu et al., 2018).
3. Monounsaturated fatty acids are prevalent in foods including olive oil, pistachio oil, and avocado oil. By lowering the levels of low-density lipoproteins and total cholesterol, these fats reduce the risk of heart diseases. Additionally, these monounsaturated fatty acids enhanced blood vessel functionality and helped to regulate blood sugar levels (Schmitz & Ecker, 2008).
4. Cold pressed oils have more balanced fatty acid compositions that are better suited for human consumption. Oilseeds naturally contain vitamin E and cold-pressed oils one of the great sources of this vitamin. Vitamin E is good for the skin, heart, brain, and hair (Rombaut et al., 2015).
5. Cold pressed oils are free from chemicals like hexane, sodium hydroxide, sodium bicarbonate, and bleaching agents Matthäus

and Brühl (2001). Triglycerides and lauric acid, which are found in large quantities in cold-pressed coconut oils, fight against weight gain and heart disease.
6. Along with other spices used in diverse cuisines, environmentally friendly, versatile, and virgin oils are praised for their natural flavor and aroma.
7. Cold-pressed oils are additive-free and do not include preservatives or solvents that are intended for human consumption (Juhaimi et al., 2018)
8. Reduced energy consumption and decreased investment cost.
9. Cold-pressed oil retains all essential fatty acids which help strengthen immunity.
10. Vitamin E is naturally found in oilseeds, Vitamin E, known for its powerful antioxidant properties, is beneficial for skin, heart, brain, and hair health (Rombaut et al., 2015).

18. Quality evaluation of cold pressed oil

- They are naturally cholesterol free, Cold pressed oil are rich in vitamins and nutrients
- They are unrefined without any chemicals
- They have high fiber content since they are unfiltered
- Cold-pressed oil penetrates the skin quickly and easily, they have less trans fatty acid

19. Cold pressing provide different purposes in food production and oil extraction

Cold pressing is one of the most common methods of extracting fruit and vegetable juices, preserving their natural flavors, colors, and nutrients. This method, which employs hydraulic pressure instead of heat pasteurization, results in juices that are fresher and nutritionally dense. Cold pressing is also instrumental in producing nut and seed kinds of butter, fruit and vegetable purees, and cold pressed beverages, all valued for their freshness and health benefits. Furthermore, cold pressing is essential in extracting high value bioactive compounds from various food sources, making them suitable for use in functional foods and supplements. The versatility of cold pressing extends to the production of fruit juice, fruit leather, and essential oils, showcasing its significance in the food industry. Although the cold press method is frequently employed in oil extraction, its significance in fruit juice production cannot be understated. Various techniques, such as the diffusion method and various presses, are also viable options for producing juice. Different types of presses are selected depending on the physical attributes of the fruit being pressed, screw presses are frequently preferred for their efficiency in handling firm fruits like apples and their adaptability in processing various fruits. Essential oils can be derived from a variety of plant and tree parts, including roots, seeds, leaves, flowers, fruits, and bark, through the cold pressing method (Busra-Cakaloglu et al., 2018).

20. Opportunities for further investigation in process optimization of cold pressed extraction

The current study has focus strong foundation for understanding the optimization of process parameters in cold pressed oil extraction. However, several unexplored areas present opportunities for future research. One key direction is the mathematical modelling and simulation of cold pressing mechanisms to predict oil yield and nutrient retention based on specific seed properties and machine parameters. These models can help design energy - efficient and high-output systems with consistent quality. Further investigation is needed into pre-treatment techniques such as enzymatic, ultrasonic, or microwave-assisted processes to increase oil recovery while preserving bioactive compounds. Future studies should also address the automation and real-time monitoring of process parameters using sensor-integrated systems, which could help small - and medium-scale enterprises maintain quality while improving overall efficiency and yield.

It would also be valuable to study various cold press extraction techniques and compare different process parameters to identify the most effective combinations for improving oil yield and quality. Additionally, conducting a design of experiments using different techniques would help in systematically optimizing these parameters. Overall, continued research in these areas has the potential to transform cold pressed oil extraction into a more scientifically optimized, consumer-trusted, and scalable technology-bringing both health benefits to consumers and economic advantages to producers.

21. Conclusions

This review paper summarizes research on various methods of essential oil extraction for various raw materials, aiming to provide stakeholders in seed oil with useful insights for selecting the most suitable extraction methods. The review provides an insight on how to optimize process parameters to improve output, quality, and nutrient retention. It helps prevent lifestyle diseases like cancer, obesity, cardiovascular ailments, and anti-aging. More recent research has focused on the nutritional value and different types of impact on the chemical composition of cold pressed oil. By optimizing process parameters, cold press oil extraction can increase output and quality while maintaining essential nutrients. Temperature, pressure, moisture, and extraction time all play a role in yield, quality, and nutritional profile. By carefully controlling these parameters, efficiency and yield can be improved by retaining valuable nutrients. Technological advances and equipment design are continuing to improve efficiency and improve cold press oil extraction. This review reports the basics of oil extraction methods and influencing parameters, and several works carried out by multiple researchers to optimize process parameters involved in cold pressed oil extraction. The difficulties involved in cold pressed oil extraction, such as variations in raw materials, equipment restrictions, and the requirement to strike a balance between yield and quality have been reviewed.

CRediT authorship contribution statement

Rathod Mahesh: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bhavi I G:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Methodology, Formal analysis, Conceptualization. **Basavaraj M Angadi:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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