International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 5 Issue 12, December - 2021, Pages:33-43

Oilseeds Processing Factors and Challenges in Connection With Global Food Insecurity and its Future Impact

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Abstract: *Edible oilseeds are cash crop foods consumed on daily basis. Since oilseeds are among highly imported and exported crops, it is influenced by advanced and intensive use of processing technology which converts nearly over 86% of total oilseed production. Out of this, the larger share of conversion was owned by countries with high processing technology, but the shortage of supply of edible oil is still managed to exist due to production problems leading to food insecurity. With the development of agricultural infrastructure and production technology advancement, a critical review of the effect of factors affecting oilseed production and processing in connection with food security and production sustainability becomes essential. In this content and extent, the research review aims to identify factors and challenges associated with oilseeds processing from industrial location theory to product maximization to nurture information for small, medium, and mega oil refineries. The consequences of food insecurity associated with dissatisfied demand, rise in oil price, chemical contamination, and oil adulteration are expected to be a future challenge in processing industries with a critical impact on economic, societal, and political instability.*

Keywords: Oil extraction; Oilseeds, Processing factors; Industrial location factors

1. INTRODUCTION

Edible oilseeds are important foods consumed every day by all people in the world in the form of seed, flavor, and supplementary food. In another perspective, it plays a developmental role in the socio-economic and political status of the citizen. Oilseeds have good business opportunities for foreign currency income that uniquely creates high job opportunities in trading, production, and conversion process. Mostly edible oilseeds are highly traded to process into edible form. Over 86% of the world's production is processed into edible oil (FAO, 2021). Due to these reasons, it is considered a technology-dependent food crop that is influenced by advanced and intensive use of processing technologies.

Usually, oilseed is cultivated as a cash crop at the global level remarkably has high chance of production decline when producers are shifting to some other option for cash earning. The oilseeds sector has several more collaborative bodies than any other crop to secure edible oil supply. Oilseed production and processing are the two major stems that encompass strong attachment easily sharing the influence of one another that further resulted in factors and challenges leading to the rise of oil demand, price, and oil adulteration with side health effects. The single variety edible vegetable oil should not be added to other oil that may not fulfill sensory, physical, and chemical requirements (NHC & SAMR, 2018). In one or another way, the success or failure of the oilseed processing sector has been associated with oilseed producers, extractors, customers, research bodies, technology suppliers, product marketing, or government bodies.

Nowadays, food insecurity is the major cause of economic, societal, and political instability as hunger and malnutrition strike certain parts of the world. Edible oil scarcity is the current critical problem which mainly comes from two sources, either lack of adequate raw material or the poor efficiency of processing technology. Thus, the review is focused on factors affecting oilseed production and processing in connection with food security, production sustainability, and impact from industrial location theory to product maximization to nurture important information for small, medium, and mega oil refineries. In this review, efforts made clarify how future impact of global oilseed, the role of major actors, the constraints, and available opportunities useful in a highly globalized and competitive world for effective edible oil processing. The review emphasizes the importance of the development of agricultural infrastructure and extraction technology advancement in food security to assure adequate oilseed production, safe and sustained processing.

2. GLOBAL OVERVIEW OF EDIBLE OILSEEDS

There are various edible oil species around the world. With the production size, the largest edible oilseeds of the world are soybean, rapeseed, sunflower, peanut, and palm kernel. However, only a few of them dominate the oilseed market. According to G. R. List (2004), nearly about 59% of worldwide edible oil consumption contains soybean and palm oils. When rapeseed is added, the total consumption reaches 75% (Rasillo-Calle et al., 2009). Soybean and rapeseed are most known in Europe, rapeseed, and sunflower in France, rapeseed in Germany, Soybean in Italy, sunflower in Spain (Verhoog, 2002). Those major oilseeds are widely cultivated in the most populous countries of the world like China, India, USA, Indonesia, and Europe. The largest edible oilseeds of the

International Journal of Academic Multidisciplinary Research (IJAMR)
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world include soybean, rapeseed, sunflower, peanut constitutes 87% of world edible oil consumption.

Edible oils are probably the most widely consumed food kinds in the world with high exposure to scientific research for the past decades over minor oilseeds. Oilseeds crops are mostly grown in the temperate zone. Oilseeds crops are produced next to cereals and pulses in some countries like Ethiopia, or the third most widely cultivated agricultural products after grain and vegetables in China, in the world estimate to make 2 – 15% of agricultural output. Oilseeds, similar to other crop seeds, are mostly grown in the temperate zone. The majority of oilseeds account for 60% of world oil grown in America and Europe (Gupta and Gupta, 2016).

Edible oils are mostly distinguished as major and minor oils; some were given in Table 1. Major oils are probably the most daily consumed food kinds in the world and have had high exposure to scientific research for the past decades over minor oilseeds. The minor seeds have relatively few users, monetary values, and social impacts due to the limited size of production. They are important in oil processing to narrow the gap between demand and supply. Some minor seeds of the world are considered major oilseeds in some other places.

Flaxseed and sesame seed are considered minor seeds at a global level but are major seeds in Ethiopia. Soybean is minor oilseed in Ethiopia but major oilseed in the USA. Because soybean makes 75% of USA domestic oil consumption (Chappell, 1998), such categories have come up with economic, technological, and scientific impacts. Those branded oilseeds have more economic benefits, foreign currency income, and other monetary values. Only in later ages, the minor oilseeds come to attention with the concept of diversification of consumption and adequacy of supply. Most technologies and extraction innovations are based on major oilseeds than minor oilseeds. Major oilseeds are high branded oilseeds with high export and currency value than minor seeds irrespective of other benefits. For instance, soybean has about 19.9% oil content (Medic et al., 2014), constituting over 50% of world consumption (El–Hamidi & Zaher, 2018), whereas sesame has about 60% oil and has only a negligible number of users irrespective of oil content and its nutritional use.

Table 1: World production of oilseeds between the years 2015 – 2018

Oilseeds	**Production 10^6 tonnes (2015 – 2018)**	**Oil category**
Soybean	334.9	Major oil
Rapeseed	72.43	Major oil
sunflower	47.8	Major oil
Peanuts	41.37	Major oil
Cottonseed	40.27	Major oil
Palm kernel	15.97	Major oil
Copra/coconut kernel	5.33	Minor oil
Flaxseed	3	Minor oil
Sesame seed	6	Minor oil

Source: FAO–UN (2018)

3. OILSEEDS PROCESSING FACTORS

Processing oilseeds into useable form is a typical food processing area gaining attention in reducing oil residual. Oilseeds are highly imported and exported crops, it is influenced by advanced and intensive use of processing technology and the larger share of conversion was owned by countries with high processing technology. Over 86% of the world's production is processed into oil while 5 – 6% of oil crops is used for seed and 8% for animal feed (FAO, 2021).

The historical development of oil expression back to the ancient age of hand processing to the rapid emerging of advanced extraction technologies in these days. The majority of the oldest procedures such as aqueous extraction was shifted to mechanical press, then to solvent extraction which is typically used in most industries. However, hydraulic presses are remained in operation mostly for pressing high–value oils that highly assist industries in obtaining quality oil. The solvent method with hexane is the most practiced in modern extraction. The solvent method is the most sophisticated processing but extracts 98 – 99% oil (Seegeler, 1983). According to Johnson and Smith (2004), in USA, 99% of industry expresses oil by solvent extracted. However, the cost of solvent and energy in the recovery process makes the process less economical.

In mass production, industries lost a high percentage of edible oil annually, leading to an edible oil shortage in the market, the rise of oil cost, adulteration of oil and health side effects, and unbalanced economic sabotage. Thus, the current effort of processing focuses on higher quality at low operational costs without loss of essential nutrients of the oil. In later ages, efforts have been made to develop efficient and low–cost processing technologies such as ultrasonic-assisted extraction, microwave-assisted extraction, and other innovative methods. The export of unprocessed oilseed is more likely higher for less developed countries due to poor process technology. Top oilseed producing countries widely worked on their edible oil processing sector for technology transfer, high yielding oilseed, and process improvements. Oil residual problems are primarily high in obsolete and traditional processing technologies commonly practiced in less developed countries.

In less developed countries mostly Africa, oilseeds are more exported than processed. The challenges related to oilseeds growers, process technology, processors, and the integration between them are addressed. In this review, those factors are thoroughly addressed the overall existing influences and challenges in the production and processing of edible oil to provide useful information for oilseed producers, processors, and researchers.

In contrast, oil processing factors are more significant than oilseed production factors in solving oil quality problems. Most factors that affect oil processing are related to processing technologies' efficiency and process variables. Thus, the import of processed oil and the export of unprocessed oilseed is more likely higher for less developed countries associated with the use of technology.

3.1 Mismatch between oilseeds production, consumption, and population growth

The world has 1.1% annual population growth rate between 2015 to 2020 (United Nations Population Fund, 2021) and world fats and oil consumption is expected to rise by 2.5 – 3% every year (Hackett, 2018). A high population growth rate makes a demanding force for a high amount of oil supply. Consumption grows faster than population growth which appears to be an economic challenge at the global level. The rise in demand would increase the price of oilseed especially when production is affected by marketing risks, trade policy, and global markets price. Oilseeds prices are normally rising with population growth, and extremely rise during rainfall scarcity and energy defect to transform oilseeds into a consumable form. Seasonal global epidemics such as COVID–19 also affect the import/export rate of oilseeds and destabilize the global market, especially for the most populous and largest importers such as China, Pakistan, Bangladesh, and India. Because they are the largest importer of major oils such as palm, soybean, sunflower, and rapeseed (Mielke., 2019). But larger exporters are safer than larger exporters for stable domestic consumption. Table 2 shows the world projected oilseed production, consumption, and price between the years 2016 to 2025. What all produced is consumed indicates scarcity. The situation of oil demand has become more complex due to the unbalanced between population growth and the oil supply. Attention to oilseed production is important to fill the gap while oilseed processing largely deals with quality.

In the long run, dissatisfied demand, oil price, chemical contamination, and oil adulteration are expected to be the future challenges in oilseed processing industries. There is the adulteration of cheap oil with high–value oil all over the world, which is unscientific that leads to commercial fraud. The severity of the problem was studied and enable to detect fraud in sesame oil (L. Zhang et al., 2017) and soybean and peanut oils (Zhao et al., 2015). According to food safety review reported by Gizaw (2019), chemical contamination accounts for 19% in developed countries coming next to food mislabeling 38% and microbial contaminations 22%. Edible oil extraction technology-related factors as an immediate cause factor have a large impact on oil shortage

Table 2: World oilseeds projections from 2016 to 2025 in 10^8 metric tonns.

Year	2016-2020	2021-2025
Production Mt	482.6	534
Consumption Mt	480.8	535.4
Price USD/t	752	839.6

Source: Adapted and modified from OECD/FAO (2016)

4. Edible oil content and health side effect factors

Percentage compositions of fatty acid indicate edible oils contain unsaturated and saturated fatty acids. Most edible oils have mainly unsaturated fats, which make them more important than animal fats for human health. From unsaturated fatty acids, omega–3 and omega–6, are essential for health obtained from oilseeds (Chandra et al., 2010). From edible oil contents, an intake of saturated fats, trans-fatty acid, and cholesterol contents are unwanted. Many oils such as sesame, soybean, cotton, corn, peanut, and olive are low–saturated acid and good for intake. Sunflower and safflower are good for health because of their high unsaturated fats. Soybean seed and olive oils have similar saturated and unsaturated fats. For most edible oil, palm oil has no trans acid but contains 50% saturated and soybean has high trans fatty acids, but trans fatty acids and high saturation are modified by interesterification and fractionation for use (G. R. List, 2004). But some edible oils cannot tolerate hardship and quickly damage when oxidized depending on the amount of peroxide value and acidity value found inside edible oil. Mostly oil nutritional qualities are managed in the extraction process and storage conditions.

5. Oilseeds processing sustainability factors

Agricultural factors affecting oilseed production are key factors responsible for sustaining oilseed supply to processing industries. Oilseed production factors include all activities that make oilseeds ready for the process, determined by agronomic techniques that include soil preparation, selection of good seasonal conditions, safe collection of ripening seeds, and appropriate storage. There is evidence that global weather change affects germination and seed fatty acid composition (Izquierdo et al., 2017). Seed content varies with the location that attributes to the variation in oil content, oil yield, and quality characteristics (Uzun et al., 2008). Cultivation rotation with other crops is also commonly practiced for better yield to be obtained. Most factors that affect oil production are related to oilseed growers' management skills.

Oilseeds with low quality cannot guarantee the extraction of quality oil. Quality and oilseed productivity varies with time and geographical location, and oilseeds type. Fresh seeds have high oil content and quality. In more developed countries, mechanized agriculture uses selected varieties, fertilizers, and proper management. According to Dossa et al. (2017), the farming parameters that affect production include ploughing (manual/mechanized), sowing period, fertilizers, pesticides, harvest period, seed drying area (home/field), and storage place. On the farm, farming inputs and oilseeds management are the major activities to obtain high yield. Such the most efficient and economic input to agricultural development would be four-fold productivity. For instance, the yield of sesame seed oilseed of smallholder farmers seldom exceeds 500 kg/ha in the pure land, whereas it is as high as 2000 kg/ha in the pure land, whereas it is as high as 2000 kg/ha in intensive production (Mkamilo, G.S. & Bedigian, 2007). Farming land has high importance in solving for adequate oilseeds production. For instance, 40.6% of organic farming is more economical than inorganic farming (Devi et al., 2007). High–yielding land and high–yielding hybrid seeds with the most suitable and economical storage facility are important before using the seed for processing or other uses.

5.1 Oil recovery of different extraction methods

As shown in Table 3, different oil extraction methods have different oil recovery and efficiency as indicated in different literature so far. Oil recovery from oilseed plants depends on the choice of extraction method, process variables, solvent type, oilseed type, and processor experience. It is clear that multiple pressing can have a considerable improvement in oil recovery, which is not economical compare to the single pressing operation. In this regard, twin screw presses are more effective. Oil extraction with an aqueous method was considered as an inefficient method but in a modified way, it can extract 90.74% oil, as reported by Chen et al. (2018). Further advanced approaches make an aqueous method to recover 94.73% oil from rapeseed (Lv & Wu, 2019). The mechanical method has a different recovery efficiency, while the solvent reaches 99.8%.

Different extraction methods have different processing variables that have a direct contribution to oil yield and quality. Process variables of mechanical press are different from solvent method or that of innovative methods but always extraction pressure is there. Process variables have an immediate effect on oil yield and quality. The choice of processing variables depends on the oilseed type, extraction method, and skill. In mechanical method of hydraulic press, oil yield depends on the major process variables such as temperature, pressure, moisture content of oilseed, and the duration of pressing (Akubude et al., 2017; Hu, Huang, Jin, & Li, 2019). In a mechanical screw press, oil yield depends on the screw rotation speed, pressure, temperature, and energy consumption of the screw press. In solvent extraction, oil yield depends on the solvent–to–solid ratio, temperature, residence time, and particle size. Various recovery indicates oil processing factors are more important to solve oil quality problems than oil scarcity as compared to oilseed production.

Table 3: Extraction methods, processing factors, and extraction efficiency

Seeds	**Extraction methods**	**Process variables**	**Sources**
Walnut	Aqueous extraction (Span 20 and PH assisted (90.74%) at 85 ºC, 1.9 g/100 g span 20, 6.0 PH, and 60 min	Solvent, Temperature, time, PH Span	Chen et al. (2018)
Pistachio oil	Mechanical (screw & hydraulic)	Temperature, time, rotation speed, roasted and defatted flour	Adrian et al. (2017)
Flaxseed	Solvent methods 36.12% yield. 107 Pa, 40 °C & 1.5 h in subcritical propane	Different solvent (hexane, subcritical propane & pressurized ethanol) Extraction	Piva et al. (2018)
Camellia oil	Mechanical (hydraulic effect analysis)	Pressure, MC, press time, and temperature	Huang et al. (2019)
Jatropha curcas seed	Solvent extraction using n–hexane 56.69%	Temperature, particle size, and solvent/solid ratio	Yusuff (2021)
Baru seed (Dipteryx alata) seeds	Supercritical CO_2 extraction	Pressure and temperature	Chañi–Paucar et al. (2021)
Jatropha curcas L. oil	Mechanical extraction by screw pressing	Temperature, rotational speed of the screw, and nozzle diameter at the end of the press	Yate et al. (2020)
Pistachio seed oil	Mechanical screw and hydraulic pressing	pressure and time for hydraulic press and rature and rotational speed for screw press.	Alvarez–ortí et al.(2017)

5.2 Factors affecting hydraulic extraction process

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Among the challenges industries have, it seems that oil industries focus on empowering personal skills and preventive machine maintenance for better extraction efficiency than effective utilization of machine process parameters. The factors affecting oilseed production frequently challenged edible oil sectors in oil extraction process. As a result, a large amount of edible oil, estimated at over a million US dollars, will be lost along with the cake annually. A loss causes an oil shortage may lead to economic sabotage such as oil adulteration, which appears to be the current industry challenge. When oil scarcity enforces the adulteration of cheap oil with high–value oil that leads to unfair commercial fraud. The severity of the adulteration problem is common fraud in food processing with high–value oil such as extra virgin olive (Yan et al., 2020). The fraud case is associated with scarcity.

It is traumatic more than anything when precious edible oils are lost along with the cake. The cause is not sporadic; every effect is caused by reason. Oil loss is due to poor processing variables, efficiency, and effectiveness of the processors. The details of factors affecting oil processing have been given in the cause-effect diagram in Fig 1. Various direct and indirect factors affect oil processing. Controlling these factors are managed to minimize oil residual to stabilize edible oil supply and price fluctuation by injecting adequate oil into the market. The controlling process of direct factors is crucial since they have an immediate cause on the extraction process. The direct factors include selecting the right types of hydraulic press, process parameters, and seed–related factors. The type of seed and the way the seed is prepared for pressing, such as seeds dehulling, de–moisturizing, heating, grounding, would vary oil yield obtained. Heat makes the seed biological structure weak and oil viscosity to assist extraction. In a particular oil processing workshop, the maximum oil yield is obtained when a good variety of oilseed is pressed by high efficient press technology under a manageable size of process variables. Among indirect factors, a well–organized workshop, trained personnel, a management body, and adequate finance are important for running production continuously and smoothly

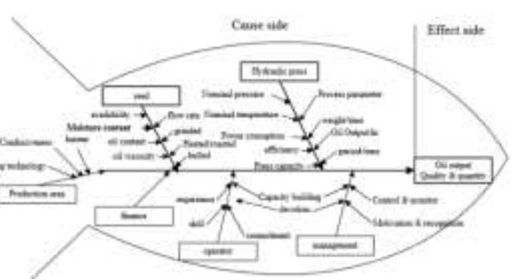

Fig 1: Cause-effect diagram for factors affecting oil extraction process

5.3 OIL EXTRACTION METHODS

There are several commercial oil extraction methods found to affect oil processing. The historical development of oil extraction begins with the emerging of extraction technology mostly during the industrial revolt. The aqueous extraction is the oldest and the easiest method whereby grounded seed is boiled in water to extract oil by float method. Aqueous extraction was used before the start of mechanical pressing and now rarely exists. As mechanical method was introduced, most aqueous extraction methods are shifted to batch pressing (hydraulic and manual mechanical presses). Through time, the transition of batch pressing was converted to continuous screw pressing and then to the chemical method. Mechanical methods are managed to exist in operation because of their advantage (Huang et al., 2019). Screw presses are more efficient than hydraulic presses due to continuous operation. Though hydraulic pressing involves intermittent batch pressing, they are remained in operation mostly for pressing high–value oils such as olive oil, camellia oil, sesame, and other oils.

Today both hydraulic and screw–pressing are considered mechanical oil extraction methods. There are different hydraulic and screw presses available with different capacities mostly preferred for low operational costs and product quality compared to the solvent method. Similar to hydraulic presses and screw presses, percolation and extractors are used in most solvent processing industries. The efforts have been made to develop efficient and low operational costs for oil processing to become successful. Thanks to researchers, there are different conventional, modified, and novel oil extraction technologies applied for processing oilseeds (Geow et al., 2021; Mwaurah et al., 2020; Quero–Jiménez et al., 2020).

The conventional oil extracting techniques implement green solvents such as water, ethanol, ethyl acetate, and carbon dioxide due to health problems (Mwaurah et al., 2020). The solvent method has sophisticated processing to separate the solvent from the oil and has expensive types of equipment such as an evaporator and disolvetizer used to separate the solvent from cake for recycling solvent using condenser. Most industries practice the solvent method with hexane in modern extraction industries. But, major shortcomings are extraction time lag, solvent consumption, and adverse thermal effects at high temperatures that can produce oxidative processes of lipids (Quero–Jiménez et al., 2020).

Currently, innovative methods such as ultrasonic-assisted extraction and microwave-assisted oil extraction, are employed in edible oil processing with the target to reduce operational costs as shown in Fig 2. Research evidence shows that different edible oil was extracted using these methods, for instance, sesame oil extracted by a steam explosion (Yi et al., 2019), moringa oleifera oil by ultrasonic-assisted extraction (Buddin et al., 2018).

The most recent extraction has focused on supercritical fluid extraction (Chañi–Paucar et al., 2021; Perina et al., 2018; Qi et al., 2019). Some comparison made among innovative method has shown that extraction using the supercritical fluid method had better oil quality than cold-press in a spiral screw press and hydraulic press extraction (Qi et al., 2019). Even though there is no evidence of the industrial application of the method in mass production, some of the literature expect supercritical fluid extraction to be the future extraction process. The extraction of baru seed oil by supercritical fluid extraction assisted by cold pressing resulted in a higher yield and lower manufacturing cost than supercritical fluid extraction (Chañi–Paucar et al., 2021).

Solvent extraction with hexane is the standard expression method widely used by oil refiners in the mass extraction line. Ethanol can be used to extract oil, replacing hexane but n-hexane is comparatively had better oil recovery (Chioma et al., 2020). Supercritical (CO_2) extraction involves the use of highly pressurized CO_2 as a solvent to extract oil and is sometimes called supercritical fluid extraction. Steam explosion is performed in apparatus equipped with the steam generator at high steam pressure and temperature to extract oil. Ultrasonic–assisted extraction uses an ultrasonic water bath with ultrasonic power frequency followed by centrifugation to extracted oil (Buddin et al., 2018) and microwave–assisted extraction uses microwave heating followed by solvent distillation.

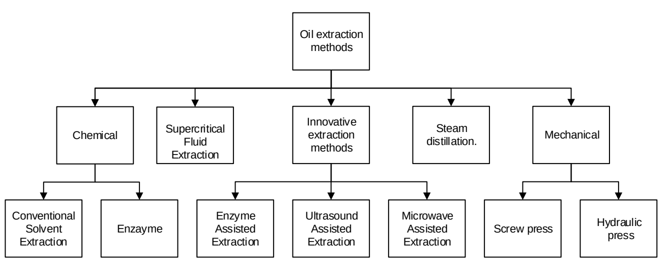

Fig 2: Oil extraction methods

5.4 OIL EXTRACTION PROCESS

Oil extraction process needs to achieve high extraction yields with maximum desirable oil contents that depend on the extraction process, type of technology, and oilseeds used. Depending on the condition of oilseeds preparation such as hulling, crushing, de–moisturizing, oil removal rates may vary. As shown in Fig 3, for screw pressing, oilseeds are extruded into collet before processing. In solvent extraction process oilseeds are diffused into a solvent that dissolves oil to facilitate liquid oil removal from the cake, but the process has complexity over that of mechanical pressing. Solvent method is the most widely used and solvent solubility, safety and cost should be considered in the selection of solvents (Q. W. Zhang et al., 2018). In both mechanical and chemical processing, pressure is needed to destructs the outer layer to squeeze the oil from the system. The action results in mass and volume reduction based on deformation characteristics of oil–containing parts.

Almost edible oils have similar processing. The most commonly used oil extraction process involves solvent or mechanical extraction (Q. W. Zhang et al., 2018). The technology used for extracting oil should be suitable for expressing oil from the seed. In solvent method, the cost of solvent and energy in the recovery process makes the process less economical. According to Bako et al. (2020), oil yield was improved through geometric configuration improvement of screw presses. On the other hand, the selection of process variables and solvent type has greatly varied the percentage recovery of oil. Process variables are also considered to reduce manufacturing costs in edible oil processing.

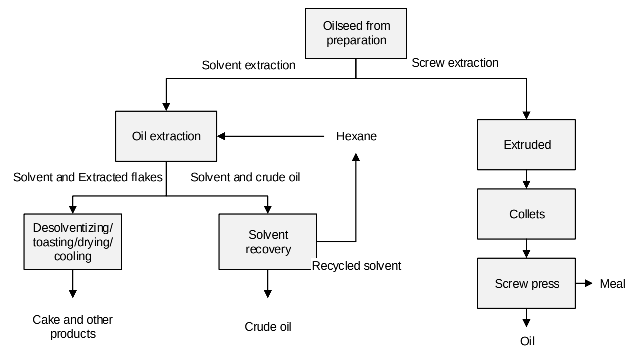

Fig 3: Solvent and mechanical oil extraction process

5.5 SCIENTIFIC EXPERIMENTATION, MODELING, AND OPTIMIZATION METHODS

Good research is based on what type of information is being collected, appropriate statistical models, and analysis type (Seltman, 2018). Therefore, the experimentation method is a primarily basic concern for any research, such as in qualitative research where researchers focus on people's beliefs, experiences, and perspectives (Haradhan, 2018) or in quantitative research where measurable variables, phenomena, and their relationships are considered. At present two–thirds of research articles are published by the use of quantitative data, which are highly valid and provide a high level of research quality (Mohajan, 2020). Oil extraction, similar to other food processing methods, response surface methodology package Box–Behnken design is widely applied in production maximization, process variables performance estimation, cost minimization and found to be advantageous over the conventional methods. Box–Behnken design (BBD) is considered a good alternative method for many problems in food processing. A good experiment design is the basics for good model development, and process optimization to simplify the process while poor design can affect the whole work, every activity, and the final result. When one model becomes unsatisfactory, the ensemble model can be used to combine the results of the prediction with another model. The hydride proposed by Huang et al. (2021) shows ensembles models are effectively functional in different engineering fields.

Latin hypercube design is an experiment method usually applied for structural analyses but not yet tried in oil extraction (Tufa et al., 2021). Since 1975 of its first development, the Latin hypercube sampling design gain extensive use with certain optimality disadvantages which later has been improved. However, many researchers, engineers, and statisticians use BBD to reduce the cost of the experiment.

Initially, the Box–Behnken design was developed by George Box for a limited class of processing problems that are difficult to approach in any other manner.

Regression analysis is the most practiced modeling technique used to study the relationship between variables and response and ANOVA is usually used for fitting regression models (Huang et al., 2019). The scientific experimentation methods for various variables and responses. In the first place, the variables to be studied must be measurable with a standard tool having specific tolerance for experimental research. None experiment research methods are common in social studies and questionnaires may be used. A pilot test was done to validate the questionnaire's clarity that it addresses the topic overall before conducting the main study. Whether it is an open-ended or close-ended questionnaire, the variable must be clear for better prediction and generalization of certain conditions between the responses and variables.

Fig 4 shows three different experiments methods usually used in most research areas. The practiced experiment techniques are single factor, multiple factor, and multiobjective techniques. In a single factor experiment, only one factor or one factor from many other factors would vary to investigate its impact on response. In a multiple factor experiment, all variables are changed according to the design method to investigate multiple factors' impact on one response. Multiple objective experiments are similar to multiple factor experiments except two or more target responses are investigated under multiple factor experiments. In some complex optimization problem scenarios, multiple factors with target two responses are considered by using multiobjective solver algorithms, such as Pareto front (Huang et al., 2020). The selection of experiment is based on the data type, accuracy required, and design objective such as samples size, range, design method (Tufa et al., 2021). For the same type of seed and process condition, there might be variations in oil yield with different modeling and experimentation techniques.

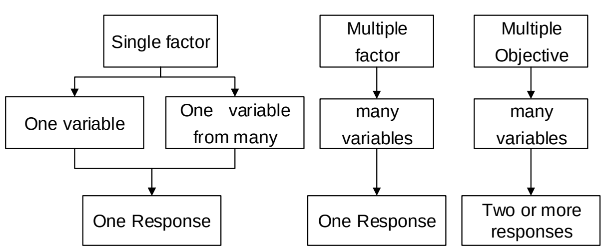

Fig 4: Scientific experimentation for various variables and responses.

6. PROCESSORS LOCATION FACTORS

The factory located, the minimum cost by which certain quantity of product or raw material transported. The factory is the center of density to its retailer or wholesaler. The first firm location theory was proposed in 1909 by weber Alfred (1962). Weberian theory of industrial location establishes a model based on the minimum cost of transport, labour, and agglomeration for maximum profit. Weber emphasizes the least cost location based on market location, nature of finished products, and transport costs. Based on the theory, oilseed producers should be located near the processors or customers since the finished product loses weight as the cake is removed during processing. If the product gains weight, processors need to be located near the market to reduce transport costs. Processors near the farm where nomads practice animal fattening and feeding also attract the area's slaughter industry and employment opportunities. Similar to plant location, the way production facilities are located matters the processing condition of any production. In this context, the decision looks for the option of minimum risk, and queuing looks for minimum production waiting time for the located facility. For the purpose of safety and security, grouping similar processes and machines has been practiced for flexibility improvement and intensive labour utilization in industries.

Oil extraction factory location determines all factors that obstacle the smooth running of factory production, operation, and supply chains. If the goal is to maximize industry output, then the processing plant should be properly located. The theory of industrial location establishes a basic theory of location. The primary evidence for the importance of industry location is based on the raw material for an effective production system. The theory shows how productivity would be affected by ' physical location of industries and also facilitate linkages among producers, processors, and product users. On the other hand, processor location requires transportation, energy, good climate, community, and pollution-free environment. Factor rating methods are usually used by experts for plant location decisions. Processors' location and facility location are important physical factors to facilitate oil production and play a vital role in linking major oilseed actors for better continuous oilseed supply to assist continuous oil processing.

Weber emphasizes the least cost location based on market location, nature of finished products, and transport costs. Based on the theory, If the finished product loses weight during processing, like that of processed oil, then the processing factory must be located near the farm to save transport costs. If the product gains weight, processors need to be located near the market to reduce transport costs, but this is not the case for oil processing. Plant location near farming has other benefits, cake left after pressing has a good market around the farm where nomads practice animal feeding further attract the slaughter industry and employment opportunities in the area.

Poorly located industries are highly susceptible to a shortage of raw material and affect the whole production life of the plant. According to Chang & Lin (2015), manufacturing plant location increases competitiveness. In a broader sense, global competition, social, economic, and political subjects are universal location issues. In this regard, processors' optimum location is decided based on product promotion and profit-making in sustaining the supply of oilseeds for processing. Otherwise, location correction would cost several years and high capital for relocation establishment. Therefore, the first establishment task must be performed by a panel of experts from lawyers, marketing experts, various consultants, executives, and industrial engineers, and other experts to minimize consequent risks

6.1 FACILITY LOCATION FACTORS

Similar to plant location, the way the facilities are located matters the processing condition of any production. In labor-intensive industries, facility location and workshop design improve labor productivity by 23% (Beshah et al., 2013). Therefore, it is important to locate facilities such as working machines, production facilities, and refining equipment. Production facilities such as building sections, storage requirements, inventory conditions are responsible for the safety and improvement of productivity.

Workplaces that are full of back and forth movement in the production process causes waste of production time, which the right facility location can solve. The production line has various value addition stages from input to product output; each should have a scientific reason for optimum process efficiency. For instance, poor inventory practices in oil extraction can cause poor material accessibility and production delay. Effective extractors only need to select value addition to maximize oil with optimum process efficiency. In such cases, unnecessary none value addition involvements are removed to establish smooth workflow throughout the system. Production efficiency is improved when different pressing and refining machines are organized/grouped according to sequential working procedures, including the product packing stage. Grouping technology is more effective in minimization of time waste and space utilization than the traditional and conventional methods. According to Boonmee et al. (2017), responsiveness to risk and disaster in emergency related to facility location problems is analyzed by decision theory and queuing theory. In this context, the decision looks for the option of minimum risk, and queuing looks for minimum production waiting time for the located facility. Both are essential steps in facility location selection to optimize working space and time.

6.2 MAJOR STAKEHOLDERS AND LINKAGE BETWEEN MAJOR ACTORS

More productive processors have a secure attachment to the knowledge of the back story of oilseeds they usually use and have a strong attachment to common values and risks sharing agents. As a value-adding and profit-making sector, processors need to process oilseed with high monetary value and nutritional benefit, which are influenced by the practice of the extraction and process technological but yielding high oil for their high oil content or high yielding breeds. Oil production is seasonal and processing fully depends on the oilseed supply and is influenced by linkage exist between producers and processors. Thus, stakeholders' involvement is highly suggested. The stakeholder theory suggests the importance of stakeholders that significantly contributes to production increment. In the stakeholder model, production process and improvement depend on owners, managers, employees, consumers, and suppliers (Argandoña, 2011). Oilseeds have several collaborative bodies than any other crop, significantly influenced by any value-adding people. In most cases, it seems owners/shareholders are more involved in decision–making than stakeholders and employees. Cooperation among major actors such as oilseed producers, extractors, customers, research bodies, appropriate technology suppliers, product marketing, and government bodies is highly beneficial and a pillar for production success.

In recent years, production organizations inherited similar goals and usually implemented by cooperation among respective institutions to defend challenges. In linkage, the major actors in the system make an open discussion to scale up strengths and opportunities to undertake actions for better handling of the threats and lessening the system's weakness. Linkage plays a vital role in solving constraints such as lack of suitable varieties, diseases, and insect–controlling pesticides, improved technology, market linkages, and price fluctuation problems. All constrain are not equal, and some can cease production and aggressively lead to product shortage. Product users and industries expertise might have experienced how difficult of being out of production or with product scarcity. Unless processors sense the challenge usually farmers faced, production cannot be effective.

7. CONCLUSION

The world has various oilseeds with a substantial rise in production and price. However, the demand is fast-moving than supply. Major oilseeds have a stronger economic impact than minor oilseeds. Factors associated with oilseed production are more important than oil processing factors to narrow the gap between demand and supply. In contrast, oil processing factors are more significant than oilseed production factors in solving oil quality problems. Oilseeds processing efficiency depends on processing technologies' efficiency, oilseed growers' management skills, and process variables. Processors' location and facility location are important physical factors to facilitate oil production and play a vital role in linking major oilseed actors for better continuous oilseed supply to assist continuous oil processing. The import of processed oil and the export of unprocessed oilseed is more likely higher for less developed countries associated with the use of technology. Dissatisfied demand, rise in oil price, chemical contamination, and oil adulteration is expected to be critical future challenge for processing industries. With interest to the quality of oil, mechanical extraction has great advantage but efficiency problem requires process optimization through effective modeling techniques and experiment design.

Acknowledgment

This research was sponsored by the National Key R&D Program of China No 2017YFD0400405

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