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New publication from ARC-AE

The Agro-Processing division of ARC-AE released a new publication titled “Processing of Oil Seeds” on 23 February 2021, authored by Ms Theresa Siebert.

What the publication is about:
South African farmers facing current economic realities are searching for new options of surviving and expanding their business. One of the many opportunities to grow markets, turnover and profits is by adding value to farm produce through processing. Food processing takes place on various scales: small-scale processing usually takes place in the household kitchen whereas large-scale food processing is done in factories and bakeries. However, regardless of the scale of food processing being undertaken, the basic processes remain unchanged. These processes are known as unit operations and are carried out in sequence.

Processing of Oil Seeds focusses on a variety of oilseed crops and contains information on a wide range of processing options for soya bean, canola, sunflower, peanut and cotton and includes:

**Soy protein concentrate:** Defatted soy meal consists of 30-35% carbohydrates. By removing the soluble carbohydrate fraction along with some flavour components, the protein concentration of the soy meal is increased. There are three different methods that can be used to concentrate soy meal:
- acid leaching method (pH 4.5)
- aqueous ethanol method (60-80%)
- moist heat - water leaching method

**Sunflower oil fat spread** or margarine is a water-in-fat emulsion which closely resembles butter and is firm in the refrigerator but melts rapidly in the mouth. It is made from a non-dairy fat and water mixture. The fat phase contains oil-soluble ingredients, e.g. mono- and diglycerides, lecithin (optional), colouring matter and vitamins. The aqueous phase (16-18%) contains water with or without added edible protein. This "milk" may be prepared by adding dried protein to water and is then pasteurised, except for pastry and kosher margarine where just water is added.

**Sunflower oil - medium scale:** The medium-scale oil processor can process 300 kg to 1 ton of sunflower seeds per hour. Sunflower seeds yield 40-60% oil of which between 65 and 80% may be extracted using medium-scale oil presses or expellers. The oil is usually cold pressed and yields high quality oil for frying, salad or shortening purposes. The oil generally retains anti-oxidants better compared to large-scale produced oil. This is important from a health and shelf-life perspective.

**Peanut flour or grits:** Peanut flour may be used as a protein supplement in milk beverages, bread and biscuits. Peanut proteins have also been incorporated in ground-beef products such as hamburgers, sausages and meatloaf.

**Peanut oil:** The Spanish peanut variety has a higher oil content than other peanut varieties. Peanut oil is produced for use in cooking due to its mild flavour and the fact that it burns at a relatively high temperature.

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Investigation of the potential use of concentrating solar thermal technology for essential oil extraction and comparison with conventional heating source

– by Mr Erence Manyako and Dr Idan Chiyanzu

Introduction

Essential oils are liquids containing volatile aroma compounds derived from plant materials that have found industrial applications in the production of perfume, cosmetics, soap, shampoo and cleaning gels. Another important application of essential oils is in the agro-food industry, where they are used to make beverages and flavour foods. Because of their fragrance, anti-oxidant and anti-microbial properties, essential oils derived from aromatic plants and spices are highly valued in the pharmaceutical, food and cosmetic industries. The yield of essential oils from essential oil bearing plants is typically between 0.005 and 10%. Because yields are low and the commercially accepted traditional extraction method, namely distillation, is energy intensive, and essential oils are high-value products, energy efficiency and sustainable energy sources, such as concentrating solar thermal (CST) technologies, have the potential to support and improve the extraction process while reducing the carbon footprint. Although the CST technologies have great potential in the agro-processing and industrial sector as a whole, they have not yet been deployed extensively as compared to other applications of solar thermal collectors for replacing fossil fuels and reducing the carbon footprint.

New smaller PTCs have been manufactured to suit process heat applications at temperatures below 300 °C. These collectors may provide industrial process heat (IPH) to a number of applications, enabling them to eliminate the use of fossil fuels.

The ARC-AE initiated a research project with the aim of investigating the potential use of CST technology for essential oil extraction. This project resulted in the construction, testing and commissioning of a solar thermal system, comprising parabolic trough mirrors, evacuated tube receivers, heat exchanger and solar tracking system. The PTC system was used to power a pilot-scale field steam distillation process for essential oil extraction from orange, lemon and mandarin peels. During the extraction, important data such as the solar thermal output, efficiency of solar distillation, temperature, essential oil yield and composition, and energy consumption of the distillation process were recorded and analysed.

For comparative analysis, further steam distillation experiments were conducted by using a laboratory glassware apparatus and pilot-scale liquefied petroleum gas (LPG)-powered steam distillation unit.

In the case of laboratory experiments, a 2.75 kW portable gas (butane) stove was used to supply heat to a 1 litre flask carrying water for steam generation, whereas for the pilot-scale LPG-powered steam distillation unit, a gas-fired boiler using a 19 kg gas cylinder was used to supply saturated steam to a cylindrical shaped pot manufactured from stainless steel 304, with a diameter of 207 mm, height of 502 mm and thickness of 2 mm.
Both the pilot-scale PTC system and LPG-powered steam distillation unit used the same distillation pot during essential oil extraction and for both cases, equal amounts of feedstock (citrus peels) were charged into the distillation pot.

Summary of findings from the research

a. Firstly, the operation of the low pressure (< 1 bar), PTC-powered steam distillation was conducted successfully, reaching a high temperature of 295 °C, with the maximum bulk temperature (345 °C) of the therminal 66 being the only limiting factor to reaching even higher temperatures.
b. The system generated a net thermal output of about 12 kW, with the collector inlet and outlet temperatures, as well as volumetric flow rate being about 50 °C, 295 °C and 100 litres/h, respectively.
c. During this successful operation, the operational steam distillation temperatures for orange, lemon and mandarin were about 96 °C. These compare well with temperatures usually expected from a steam distillation operating under atmospheric conditions.
d. The above operating conditions created by the PTC-powered essential oil steam distillation created an enabling environment for essential oils to break free from essential oil plants and produce essential oils at a quantity and quality matching that found in the literature.
e. The average yields of orange, lemon and mandarin essential oils were found to be 0.67, 0.53 and 1.09%, whereas for gas-powered steam distillation the average yields were 0.65, 0.44 and 1.17% for orange, lemon and mandarin peels, respectively. Concerning the gas- and PTC-powered experiments, the majority of essential oil yields from individual experiments fell within the expected ranges.
f. Laboratory tests were also conducted and the majority of the experiments were greatly improved in terms of yields when compared to pilot-scale experiments, which indicates that the pilot-scale experiments can still be improved further.
g. With regard to energy efficiency, the two pilot-scale field experiments were evaluated and the results compared. The gas-powered steam distillation experiment showed that the overall efficiency of the system was 70.4%, with a high probability of getting even less, considering the fact that the boiler was not thermally insulated. On the other hand, the overall system efficiency of the PTC-powered steam distillation was found to be 54.99%, which is 15.41% less than that of the gas-powered steam distillation. Although the overall system efficiency is relatively small, it still compares very well with other similar research studies on CST technologies and in some cases a little bigger.
h. Having conducted a techno-economic review of a PTC system, data collection and analysis of yield, essential oil quality, distillation efficiency and solar resource assessment, it can be concluded that PTC can compete with LPG and possibly other fuel sources, but it depends on the fluctuation of the fuel price. Each fuel selected has its own price and a different payback period associated with replacing that particular fuel. The higher the fuel price, the better the economics for CST projects. It is thus advisable that for each case of evaluating economic and financial viability of an industrial process heat CST project, prevailing factors must be analysed as it is not only the fuel that affects the payback period; discount rates, current costs of CST technology components, DNI radiation all affect the payback time.

Conclusions

It was observed that results from PTC compared well with a fuel gas-powered system, thus rendering the PTC sufficient for deployment in agro-based industrial applications. The PTC offered much more benefits, such as continuous steady supply of energy as long there was sufficient sunlight, lower operational costs and reduced carbon footprint. This technology is the best among other concentrating technologies in terms of the technology maturity and high number of deployments around the world. Many industrial processes and electricity production turbines can benefit from it and significantly reduce carbon emissions.

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Poor performance of drip irrigation in smallholder systems is cause for serious concern
- by Dr Macdex Mutema, Ms Manoshi Mothapo, Dr Khumbulani Dhavu, Ms Judith Seopa and Mr Maduna Ncokazi

Smallholder farmers are an important component of the South African agriculture sector and water use by the smallholder sector adds to the total water demand by agriculture in the country. It is common knowledge that agriculture consumes the bulk of the water used in countries whose economies are strongly driven by agriculture. Ironically, irrigated agriculture is also the least efficient in terms of water use. For example, South African irrigation systems are reported to waste at least 43% of the water supplied to them. The smallholder irrigation sector contributes to this low efficiency of water utilisation.

The government of South Africa requested the agriculture sector to reduce the wastage of water, which has driven the development of innovative water saving technologies and approaches in the supply, delivery and application spectrum. The drip irrigation system has been widely adopted by both large-scale and smallholder irrigators for field level water application because of its known high efficiency and ability to save water. However, the performance level of drip irrigation technology differs between large-scale and smallholder irrigators, and amongst the individual farmers within these two groups. It is generally accepted that performance is lower in the smallholder than large-scale irrigator group due to, in summary, limited resource endowment and access thereof. However, the level of drip irrigation technology performance is largely unknown due to lack of consistent and systematic scientific assessments.

The ARC-AE did a snap-shot survey of four Agri-Parks (namely Rooiwal, Soshanguve, Tarlton and Westonaria) in Gauteng province where drip irrigation technology is the main method of applying water to crops. The Agri-Parks are run by groups of smallholder farmers who either work in cooperatives on the same pieces of land or as individuals on individually allocated pieces of land within the perimeter of the Agri-Park. The survey, which focused on water delivery and application, revealed many key challenges that negatively affect the overall performance of the drip irrigation systems.
The following stood out in all the surveyed Agri-Parks:

- **Leakages in main pipelines (especially at joints)**
  The irrigation systems were installed a while ago and some pipes have run their course. Hence, replacements are needed. While there is a general lack of the necessary skills amongst the farmers, the tenure system in place is not helpful either. The farmers are generally not interested in investing their own money to replace the worn out pipes and parts. There is also no clear ownership structure for common pipelines (e.g. the main supply), because farmers operating in an Agri-Park are not necessarily a coherent group.

- **Damaged drip lines with water jetting out**
  This was another very serious problem identified across all four Agri-Parks. While this was prevalent in the tunnels managed by both individuals and groups of farmers, there were no signs of serious attempts to attend to the damage. This also pointed to a lack of interest by farmers to invest their own resources and a general lack of skills to attend to the damage.
  
  There was also no maintenance and/or drip line replacement plan in place which the farmers could try to follow.

- **Poor sealing at end caps, which results in water gushing out**
  It was also surprising to observe the high levels of leakages at the end caps with no evidence of adequate attempts by smallholder farmers across all the surveyed Agri-Parks to attend to the problem.
  
  There is probably no cognizance of the impact of such losses to the overall performance of agriculture with regard to water use efficiency.

- **Uneven surfaces, which result in suspended drip pipes**
  This was also a common problem across the surveyed Agri-Parks. The problem with suspended drip lines is that after emitting out of the pipes, the water drops with no critical mass to drop onto the ground surface will migrate down along the pipe. The migrating drops will coalesce with drops from other emitters and only fall to the ground when the combined mass is big enough or when the drip line is intercepted by the ground surface. The end result is poor water distribution along the pipe.

While this was just a snap-shot survey and only a few of the observations are reported here, it is clear that the state of water losses at the Agri-Parks should be a cause for concern amongst water researchers and practitioners. More serious investigations are necessary to quantify the losses with a view to bring to perspective their significance and also explore potential solutions and priorities. The potential solutions will need to relieve development partners from the extra burden of, for example, procuring spare parts for the infrastructure and employing people to fix the damage that inevitably occurs as the systems are used.

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Material testing is a respected and established technique that is used to ascertain both the physical and mechanical properties of raw materials and components. It can be used to examine almost anything from human hair to steel, ceramics or composite materials. Material testing is performed for a variety of reasons and can provide a wealth of information about the tested materials, prototypes or product samples. The data collected during testing and the final test results can be very useful to engineers, designers, production managers and others. Some of the reasons material testing is important include:

- Meeting requirements of regulatory agencies.
- Selecting appropriate materials and treatments for an application.
- Evaluating product design or improvement specifications.
- Verifying a production process.

Regulatory Compliance
Many products are used in critical applications where a failure could result in extensive damage or injury. Some examples are manufactured fasteners and parts that have a vital role in maintaining the safety of aircraft, bridges, vehicles, nuclear reactors, military equipment or medical implants. In addition, many jurisdictions have adopted legislation restricting the use of hazardous materials. In cases like these, governments and regulatory bodies set compliance requirements that must be met by manufacturers. Companies must adhere to these standards, which generally specify test procedures to prove compliance.

Appropriate Material and Treatment Selection
The quality of a material going into a manufactured product is as important as the reliability of the production process. Material testing helps us to understand and quantify whether a specific material or treatment is suitable for a particular application. With the wide variety of materials and treatments available in the marketplace, testing can help narrow down the choices to the most appropriate selection for the intended use. As mentioned before, for many industry applications, testing is performed to certify material to a given standard or specification, or to verify that it meets other stringent criteria before it is put into use.

Not only is testing commonly relied on for material selection and choosing a reliable supplier, it is frequently used as a verification process to be sure that the material received from a new supplier is what was ordered. Material testing may include methods that yield information about the structure or mechanical properties of the material. It may also make sense to verify the composition or elemental content of the material with an instrumental or classical wet chemical analysis technique.

Product Design and Improvement
It is typical for a business to purchase mechanical testing services when specifying material for a new product design. Testing may be performed to evaluate mechanical properties such as strength, hardness, elasticity and fracture toughness. Corrosion testing can determine if the material will hold up under given conditions such as humidity or a salt water environment. When an application requires more durable or more corrosion-resistant metals, this can often be attained with the addition of treatments. When appropriate, the material may be heat treated prior to testing to determine that the specified results have been achieved.
Production Processes
Testing is an essential part of both design and manufacturing processes, not only when safety is a concern but also for any company committed to selling reliable products and minimizing damage and costs if problems do surface. Testing is often performed early on during product development to evaluate a planned production process. It can also be just as relevant to provide validation for final products on an ongoing basis. Various types of non-destructive testing services are used to evaluate finished products without causing damage to the items.

Material testing also plays a large role in failure analysis investigations to help identify defective products, inadequate materials and, ultimately, the cause of a failure.

Material Testing Machines
Universal material testing machines are configurable for a range of applications. This can be accomplished by selecting the appropriate load cell, sample holder grip, material testing software and any required accessories such as thermal cabinets, high temperature, weathering, etc.

Application of Material Testing Machine and Ongoing Research
Tensile strength is one of the major parameters in the description of the stress-strain. Tensile testing is by far the best method in testing of material and determination of tensile strength. Elongation can also be used to determine the elongation of fracture as a toughness measurement of material. Testing of material includes the following:
- Tensile Strength
- Deformation Strength
- Young’s Modulus
- Ductility
- Toughness
- Compression
- Elongation

The team has tested polymer (plastics and textile) materials used in the agricultural sector for irrigation and planting. This includes tensile testing of moistube irrigation (MTI) tube and roll planter (PLA). The facilities also include exposure of the materials to different weathering conditions using the Climate Chamber for accelerated and depressed temperature ageing and the QUV Accelerated Weathering Tester. Research on compression of Agrimats made from algae and any other biomass waste, such as bagasse, is ongoing. Agrimats are used as mulching material in agriculture, which aims to replace traditional plastic-based mulch mats with purely organic material that has the potential to release nutrients into the soil.

Climate chamber used for exposing material to accelerated and depressed temperature ageing (hosted by ARC-AE)

QUV accelerated weathering tester (hosted by ARC-AE)

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Bernoulli’s principle, which is an expression of the conservation of energy in fluid dynamics, states that if there is a decrease in pressure or potential energy of a fluid, the speed of the fluid will increase simultaneously.

This principle is named after the mathematician Daniel Bernoulli, who lived in Basel, Switzerland. He published his book *Hydrodynamica* in 1738, in which he described the behaviour of fluids when they are in motion. He is regarded as the father of fluid dynamics.

Bernoulli asserted in his book that when the velocity of an incompressible fluid increases, for example when the flow area of a pipe or canal decreases, the pressure will decrease. Thus the fluid exercises less pressure on its surroundings, and conversely, where the fluid is moving slower it exercises greater pressure on its surroundings.

The Bernoulli equation is equivalent to Newton’s conservation of energy principle, but applied to flowing fluids. Liquids and gases are considered to be fluidic substances as they can flow and take on different shapes. The “Bernoulli effect” is the lowering of fluid pressure in regions where the flow velocity is increased. This decrease in pressure where a flow path of a fluid is constricted may seem counter-intuitive, but not when you consider the pressure to be energy dense. In the high velocity flow through the constriction, kinetic energy must increase at the expense of pressure energy.

The Bernoulli equation applied to a constriction in a tube is illustrated below. Here, P is pressure, \( \rho \) the density of the fluid, \( v \) its velocity, \( A \) the cross-sectional area of the tube and \( h \) the height of the fluid at a given point. In this case the difference in height between points 1 and 2 is zero.

\[
\frac{v^2}{2g} + \frac{p}{\rho g} + h = \text{Constant}
\]

where
\[
\begin{align*}
\rho &= \text{density (for water 1 000 kg/m}^3) \\
v &= \text{flow velocity [m/s]} \\
g &= \text{gravitational acceleration (10 m/s}^2) \\
p &= \text{water pressure head [m]} \\
h &= \text{static difference in elevation [m]}
\end{align*}
\]

The first part of the equation, namely \( v^2/2g \), is the velocity head.

Between sections 1 and 2 the Bernoulli equation may be used as follows:
\[
\frac{v_1^2}{2g} + \frac{p_1}{\rho g} + h_1 = \frac{v_2^2}{2g} + \frac{p_2}{\rho g} + h_2 + h_f
\]

where \( h_f \) = frictional loss between section 1 and section 2 (m water depth).

The Bernoulli equation can be used to describe conditions at any point in a pipeline. One of the pressures \( p_1 \) or \( p_2 \) is usually unknown. The remaining variables, except the friction loss (\( h_f \)), are usually known. Where liquid (e.g. water) flows in pipes, an energy or friction loss occurs because pipes are not frictionless. Numerous equations have already been compiled for the determination of friction loss. Other applications of the Bernoulli equation include canal flow and air/gas flow calculations and several venturi applications. The ability of an airplane to fly as well as the propulsion of a sailboat by wind are also ascribed to Bernoulli’s principle.

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