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Manufacturing of Sugar Measurement Devices

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Annotation: This report describes the methods employed to fabricate a sugar measurement device that will assist the development of an automatic sugar cane harvester. A sugar measurement device is essential for a sugar cane harvester to predict the quality of the harvested sugar cane at the point of harvest. This capability would allow better management of sugar cane harvesting. For example, harvested sugar cane of different quality could be controlled separately prior to transport by different means. People currently evaluate the quality of sugar cane after the harvest at the sugar mill. This means that the quality of the harvested cane cannot be changed. This report covers the design, construction, calibration, and testing of a sugar measurement device for a sugar cane harvester.

The sugar measurement device itself consists of an optical assembly and a mount. The optical assembly is the most critical component since it contains a sugar mass measurement device and is responsible for accurately calibrating sugar mass measurements. The mount is necessary for mounting the optical assembly in a sugar cane harvester. Calibration involves determining the parameters that characterize the response of a sugar mass measurement device to the measured sugar.

An optical assembly for measuring the sugar mass contained within a pipe based on diffuse reflectance theory is constructed. The sensor is a fiber optic diffuse reflectance sensor with a controlled exit angle. An acquisition device is used for storing the data collected by the sensor. It also provides a mechanism to evaluate the properties of the sugar mass measurement device, to determine the calibration parameters of the measurement and to validate the device's performance.

1. Introduction to Sugar Measurement Devices

The determination of concentrations of sugar stock solution is a prerequisite for the production of sugar measurement devices (SMD) based on photometric measurements. In principle, the determination can be achieved by measuring the sugar solution density with a simple oscillating fork type densitometer. In this work, sugar densitometers with custom made precision density sensor were designed to cover a wide variety of sugar stock solutions (1 600 kg/m3 for hydrous glucose up to 1 232 kg/m3 for anhydrous saccharose) and tested.

For the measurement of sugar concentration, an oscillating fork type density measurement system is advantageous because it is simple, robust and commercially available from several manufacturers. This principle was adopted for the design of sugar measurement devices (SMD) already in 2008. The operation of this fine sugar measurement device proceeds in the following framework. The filtration and de-aeration of the sample is performed in a separate station using a homogenizer. After the removal of sample, the fine sugar is put into the designated compartment of the measuring cup and covered by tap water. After a certain equilibration time, sugar measurement is started by immersing the measuring cup in water. During the period of measurement, the tuning fork is oscillating and the sample density is determined from the observed resonance frequency shift as the sensitivity of the tuning fork is strongly affected by the sample density. Such fine sugar measuring SMD requires a density meter to be operative prior to the construction of a sugar concentration device [1].

The measurement of sugar concentration of hydrous solutions 1% w/w – 0.4% w/w can be accomplished in several commercial density meters. The following very concerned about the construction of a measurement system for densitometry. Since the sensitivity of the oscillating membrane density meter to temperature is low, it would directly measure temperature-compensated sugar stock density. Moreover, very high sensitivity (1 × 10 - 3 kg/m3) for frequency measurements could be realized making it best option for widely used less troublesome. Furthermore, activation of the Peltier element and development of a measurement algorithm increased testability. [2][3][4][5]

2. Types of Sugar Measurement Devices

Sugar quality is the most important measurement in milling and manufacturing units. Absolute values of Polarization, Brix and Total Soluble Solid (TSS) are essential for manufacturers to ensure the correct quality of the sugar. Well established devices for Polarization measurement do exist in the market used widely by manufacturers. Ancillar devices to correct the measurements can be added to these devices to broaden the usage [6]. More modern measurement devices for TSS, brix and density exist but technology is still maturing. Sometimes optical sensors for TSS are used in harsh environments. Optical sensors introduced for these applications are better suited to well controlled environments. A universal device for these measurements has been designed which has the core measurement sections from Polarization measurement devices. Patented designs for sugar gathering and the measuring chamber have been implemented which protect the measurement optics and electronics from being contaminated. Other advanced measuring devices used today do not have such robust designs and therefore they are not suited for all environments.

Sugar is a widely produced and consumed commodity. Worldwide production runs into *** value with the sugar being consumed in a myriad of companies producing food products, confectionery and many pharmaceuticals. The sugar is extracted from cane or beet in sugary sap form or various other concentrations through a miriad of complex processes. At all stages of the supply chain there are many measurement devices deployed to determine sugar quality. The most important measurements in sugar quality are Polarization values, Brix values and Total Soluble Solid (TSS) values. Many devices do exist to measure Polarization values either in a direct or indirect way. In direct Polarization devices the sugar is converged into a sensing chamber where the angle of polarisation is measured. A balance weight to maintain or retain a fixed volume of sugar is maintaining the position in the measuring chamber. Older, well established and much used Polarization measurement devices use a tuning fork to achieve this. Other designs have been patented with the help of silica rods. Both these designs are widely used in the sugar industry and often optimizations/developments can be added to enhance their robustness. [3][7][2]

2.1. Mechanical Devices

Sugar measurement may be made by means of weighing machines. It is assumed that such a device will measure only sugar and not other similar materials. Such devices are therefore precise and no error is experienced, neither in the weight nor in the resulting quantity of syrup. These devices, however, are expensive to manufacture and are less portable, making it inconvenient for use in smaller shops and kiosks. Measuring cylinders may also be considered a sugar measuring device. As the weight of sugar differs from one country to another, measuring cylinders lose their utility as working devices for sugar measurement in international trade. Due to this shortcoming, measuring cylinders cannot be considered a sugar measurement device. Although hydrometers or gravimetrical devices may be a device for measuring sugar, hydrogen-test shave-off devices, refractometers and gravity tests are presently included. The sugar measurement device, a widely used device in the sugar trading industry, a mechanical device composed of a sugar cup and a balancing vessel, was found to detect any possible attempt of counterfeiting. [2][4][8][9]

2.2. Electronic Devices

Electronic sugar testing devices are modernized devices that use electrical techniques to determine sugar levels in raw or processed substances. These devices are highly accepted as they give accurate results and are usable without previous knowledge about sugar analysis. Also, they are portable in size and battery-operated. Electronic measuring devices contain sensors, which are mounted in the measuring chamber, chemically selective measuring electrodes, and amplifiers with controllers and regulating devices. Sensors detect the measured value from the measured system and output a signal according to a predetermined law. Chemical electrodes convert the measured analyzer concentration into an electric potential difference. Amplifiers transform the analog signal into a logical electronic signal and transmit it to the controller. The latter measures and compares the signal with predetermined values and creates regulating letters according to which the signal is further processed. The comparison of the determined and pre-determined conditions together with the slowed controller allows the anomaly changes in the sugar concentration to be quickly corrected. Regulating devices transform the digital signal into the analog form readable to people.

The measuring cell of electronic devices with ion-sensitive electrodes is always kept hydrated.

The electrode has to be patched before measuring, which can minimally change the measuring conditions and affect the measuring time and the performance of the device. The same type of measuring cell is designed for both electronic devices and mechanical devices; only the materials used differ. Still, the error is two times bigger than that of mechanical devices. Electronic devices measure at a certain temperature. Electronic devices differ from mechanical and smart devices in that they give output signals showing sugar concentration, which directly indicates the measured value. Mechanical or smart devices require calculation or logic work with the output signal to indicate the determined value. [10][11][12][13]

2.3. Smart Devices

Smart devices are the invention of the modern world and are an advancement of electronic devices. Smart devices are a type of electronic devices that rely on the internet and cloud for their operation. Just like electronic devices, they use a variety of electronic circuits comprising various components. However, smart devices are on the higher level of the technology pyramid. A smart device is a product that can connect additional smart accessories or peripherals to enhance performance or provide added functionality. Many smart devices include accessories that include connected sensors, displays, lights, and cameras. An example of a smart device is a smartphone that consists of apps, sensors, displays, and cameras controlled by a local microcontroller. Smart devices take an input from the additional smart accessories and send it via the internet to a cloud service. This service performs heavy processing on the data and sends a response back to the smart device, which performs actions based on the received data. The response data is transmitted in the form of measurable quantities and serves as the output of the cloud service.

Among the various types of smart devices, smart sugar measurement devices are one of the smart devices used to measure sugar content in a liquid sample. These devices or systems are used to detect sugar content in beverages such as sugar sweetened beverages or even raw sugar syrup for further processing. Smart sugar measurement devices provide a high level of accuracy and real-time monitoring of the sugar content. Smart sugar measurement devices and systems can be used in sugar industries, beverage factories, custom rehabilitations, and universities for research purposes. An elaborate description of the smart sugar measurement devices is provided in this section.

Smart sugar measurement devices or systems are devices with two types of devices, such as a local SMART device and a cloud service, through which data on sugar content is transferred from one device to the other. This external cloud service providing the strategies for analysis and detection is not embedded inside the smart sugar measurement device. Due to the architectural difference between a smart sugar measurement device and the sugar measurement device, these devices are segregated. The core parts or internal devices that make a smart sugar measurement device smart and capable of detecting sugar content are microcontroller-unit based devices such as temperature control circuits, colour measuring circuits, reflectance measurement circuits, spectroscopy measurement circuits, controlled input/output devices, and LCD display devices with control circuits. [14][15][16][17]

3. Market Analysis

The sugar measurement devices market is rapidly evolving with the advent of new technologies and methodologies. Currently, sugar measurement devices comprise polarimeters, colorimeters, and refractometers. The market is witnessing new product launches with advanced designs and efficient methods. A new portable polarimeter was launched to quickly and accurately measure sugar using optic measurement technology. A powerful dual-lens digital sugar refractometer with easy one-handed operation was introduced. Furthermore, a 3-in-1 portable digital color and sugar tester was launched in the market. It is expected that all sectors of the sugar measurement devices market will expand, with refractometers capturing the majority of the market share. This is primarily due to the devices enabling direct measurement of sugar content instantly in an easy and reliable way. Simultaneously, production upgrades along with the preference of manufacturers for efficient equipment alternatives are expected to boost the growth of sugar measurement devices. Moreover, sugar measurement devices have applications in bakery, dairy, and fruit juice sectors. Rising health concerns over sugar intake are anticipated to improve the sugar measurement devices market.

The main end-users of sugar measurement devices are sugar plants/sugar industries and quality testing laboratories, health departments, and sugary product manufacturers in both public and private sectors. Early detection of sugar-borne diseases and regulatory measures are also driving the sugar measurement devices market. Price fluctuations in raw materials have caused fluctuations in sugar prices on a global scale, which has created the need for regulating the sugar content in the product. This is anticipated to provide growth opportunities for companies manufacturing sugar measurement devices. Sugar measurement devices require high initial investments, which is expected to restrain the market growth as many small-scale industries do not prefer expensive measuring devices, restricting the companies from entering such sectors.

The number of producers is fewer than that of manufacturers of sugar measurement devices. Key companies in the sugar measurement devices market are Bellingham + Stanley, Anton Paar, A.K.Cohens, Azonix, GANGDONG, GREE, HAINA, amongst others. [18][19]

3.1. Current Market Trends

Globally, the sugar measurement device market is moving toward automation and sophisticated equipment that can control measurement processes. Throughout the forecast period, demand for integrated sensor and analyzer solutions based on advanced optical measurement systems is projected to drive the market expansion. To further develop and commercialize measurement and control solutions, equipment manufacturers, suppliers, industrial users, and research laboratories have forged partnerships for R&D programs in the sugar industry.

Countries such as Brazil, India, China, Thailand, and the United States hold the most significant share of the sugar market. Brazil is the leading sugar cane manufacturer globally, with over 9 million hectares of cultivation yielding an annual 580 million tons of cane. These countries have poorly optimized sugar separation and purification processes and therefore want to outsource sugar measurement devices. As a research-driven industry, sugar based measurement product manufacturers can support sugar factories directly in the measurement area by providing improved instruments for reducing environmental emissions, optimum energy consumption, and better product quality. In the past, sugar production processes were widely researched to improve process quality and control. However, recent developments indicate that the process has not been optimized enough. There remains astonishingly high levels of sugar loss associated with poor separation and purification control. As a result, manufacturers are more open to contact product developers who can assist in improving measurement accuracy and, thus, process optimization.

3.2. Target Demographics

There are primarily two types of stakeholders who may be addressed through bespoke systems. First, there are firms with significant investments in the sugar production sector. These include multinational agricultural processing giants with sugar processing plants, as well as other major refiners with multiple products. The second group consists of private individuals and start-up companies looking to invest in sugar manufacturing. Therefore, the target demographics for bespoke systems are:

- Target Demographic 1: Refiners of Sugar • Target Demographic 2: Individual and Start-Up Companies Involved in Sugar Manufacturing

Target Demographic 1: Refiners of Sugar

These firms are typically well-established organizations with significant capital base and extensive financial controls. Most of them are multinational companies with sugar raw material extraction operations and multiple sugar production facilities in various geographic locations. Furthermore, most sugar processing plants tend to be quite large, resulting in high demands for production control systems. In terms of the product itself, if sugar supply increases relative to market demand, processing plants contemplate increasing output by expanding production. This also involves increasing preliminary equipment procurements, which is a process that can often take years. On the other hand, if market demand for sugar decreases, this is very likely to result in one or more of the processing plants closing to avoid huge losses being incurred. Most organizations will similarly be looking at investing in restrictions or controls on production before other forms of cheaper sugar from other municipalities can be sourced. Due to the high process complexity and possible risk of financial and economic loss, large corporations will typically employ a wide variety of controls throughout their facilities and the sugar manufacture and processing plant on a local level.

Target Demographic 2: Individual and Start-Up Companies Involved in Sugar Manufacturing

The target demographic for this business, in terms of the bespoke systems, includes companies and individuals just starting to become involved in the sugar industry. These are typically less well-established firms with less established income flows and financial resources. This makes it unlikely that they would be able to afford to invest heavily in controlling systems. On the other hand, these companies' products would typically be much smaller in order and supply, which means less well-established firms are able to supply equipment and systems to these organizations that are far less demanding and difficult to control for. [20][21]

3.3. Competitive Landscape

The market for sugar measurement devices is composed of a few actively competing nations. Alaris Systems and Tanaka manufacture the devices ahead of Indian competitors, who are making inroads. With the advent of India's Solid Control Order, the first steps have been made. Tanaka and Alaris Systems have recently commissioned expansions for sugar analyzers in a union of sugar factories in India. The advent of sugar factories made the union, reducing the throughput of 6 to 8 factories down to 1, opened the door for Tanaka and Alaris and early smart devices.

Tanaka has both optical and polarimeter based sugar analyzers successfully working in India, but chiefly deals with optical devices. These analyzers are internet accessible enabling remote monitoring and troubleshooting. Alaris Systems have few Optical Analyzers and Polarimeter for Fixed and Continuous Forward and Return Brix Measurement are also marketed. Major sugar factories deal with Alaris Systems and as such, a small monopoly. The success of Alaris is fueled by untended devices, enabling unhindered high volume productivity and peak readings overnight and during short crushing season and maximizing the mill crushing time.

Entry of Indian players through an invented 8 light and state-of-art but costing lesser devices than Tanaka and Alaris, shorter lead time of 2 to 3 months and aggressive pricing competitions stemmed some earlier successes. With Indian competitors winning with smaller mills, entry to bigger group of mills constitutes the road ahead. Big organization would need bigger systems and devices with higher accuracy of better designs, sharper tuners, more light filtering channels, new technologies in components and peripherals and precision series of monochromators. [22]

4. Design and Development Process

The design and development process of a sugar measurement device involves several key phases, including conceptual design, prototyping, testing, and validation. The device is designed to be used in sugar laboratories for measuring the concentration of sugar in syrup using brix refractometry. The electronic structure, housing, and measurement probe must be designed for accurate measurements, and the end-user interface of the display device must be designed for user-friendliness.

The conceptual design phase involves comprehensive research into brix measurement using refractometry principles, the characteristics of the desired sugar measurement device, and the technical feasibility of these characteristics. To this end, an extensive study and a brainstorming session with industry professionals are conducted. The concept is drawn, and techniques for displaying data using an electrical measuring device are mapped. High-level assumptions are made, and focus is placed on three crucial components: the optical measurement probe itself, the display device housing and electrical structure, and the analysis of the data.

Prototyping is done in several iterations based on the information gathered in the conceptual design phase, resulting in workable technology in its most simple form. Early prototyping is done to limit effort on developing unnecessary details. This phase consists of three prototypes: a digital optical probe, a display device with embedded software, and a calibration stand for the sensor. Effort is limited on crafting prototypes that look physically appealing to prevent hasty expenditure of time. It is also specific which functionality prior to coding and constructing a prototype is necessary. Feedback on the direction of the concepts from industry professionals is also sought.

The refined design is extensively tested. The calibration and settings are first tested by functional tests. The speed of calibration, adjustments to the array, and the need for extra adjustments to achieve similar measurements as the industry are analyzed. The output of the optical sensor is also tested. Efforts to improve measurements with the refractometer on bright solutions to come closer to the real refractive index are discussed with industry professionals. The dependability of the output is analyzed by testing it on solutions with known sugar compositions, and the handling of the probe is evaluated. [23][24]

4.1. Conceptual Design

In order to create the sugar measurement devices, it became necessary to conceptualize and design them. Due to the quality of the measurement and control that users needed, the design process was complex and it was considered of utmost importance to do it correctly from the beginning. The sugar measurement devices will be comprised of three different models; two sugar transducer models and one sugar controller model. Both sugar transducer models are touch screen based and are able to operate automatically for the measurement of sugar. The major differences between these two models are their range of measurements and their dimensions. The sugar controller model is manually operated.

The models were initialized with two different concepts for each model. This was decided upon in order to explore various alternatives and their advantages regarding its reliability and cost of manufacturing. The general idea of early sugar measurement devices was searched through various resources. The purpose of early sugar measurement devices was to create a portative sugar measurement tool. The basic idea of this model is similar to early measuring devices; placing a cuvette in a holder, taking a measurement by putting the cuvette into a path of view where it is illuminated from an angle and activated a photodiod. Illuminated area of this cuvette was in a specifiable path.

The design keeps the existing path of early prototype devices so that the devices could be compact and reliable. In addition, it requires mechanical parts that exist on the market. These mechanical parts include a stepper motor, an optical filter, a cuvette holder, a light source and housing parts. The initial ejection achieved statics modeled, conceptual 3D design. The device will be tested and further detail design will be held after its prototyping. Further information on its function will not be provided in this initial design. The other design being rejected is actually a simplified prototype of the initial design. This design faced a lot of constraints during its review and initial prototyping, however, it was worth to invest efforts to try because the idea was very novel. The design required only a few mechanical parts; a cutter, a light source, a photodiod and cuvettes. [25][26]

4.2. Prototyping

Some of the essential things that should be done to prototype the sugar measurement device are as follows. The sugar measurement device prototype is designed with a lid and transparent cup for sugar. It contains two holes; one to refill sugar and another hole for taking measurements, and it also contains a microcontroller in a plastic enclosure attached to one side. Complete 3D model parts are to be printed on a 3D printer with a layer thickness of 0.1 mm and proper support. Some parts are to be printed with different colors, like white and black.

Before printing parts on 3D printers, settings are applied in the software where layer height is set to 0.1 mm, infill density is set to 20 %, printing speed is set to 40 mm/s, wall thickness is set to 0.8 mm, temperature is set to 220 and 60 °C for nozzle and build plates respectively. After slicing the steps with a 3D printer, the parts are to be printed on a 3D printer. After printing, parts are cleaned to remove extra attached plastic materials. Then, all wire connections of the sensors, motors, and microcontroller are done. The body parts are connected using screws, and fully assembled parts of the sugar measurement device are made. Connect the display with an I2C connection with the mainboard.

The running environment is set in the software. The includes initialization of I2C connection modules, defining the motors used, and some functions like get data, read, and take measurements. After compiling and uploading the to microcontroller one, connect the measuring mode and fill in sugar on the cup. After doing these steps, the design and development of the sugar measurement device are finished. [2][4]

4.3. Testing and Validation

Once the prototypes were fully developed and assembled, testing and validation of the functionality followed. This phase involved testing the measurement device for its strength measurement accuracy and calibration performance. Some general background information about the laws related to strength measurement is provided.

The validation of the measurement device required two reference devices for check measurements. Two kinds of reference weights were used: 500 g fixed weights and beam balance, which were serially linked to check the frequency against the frequency of the developed weight measurement device. Beam balance is a very sophisticated instrument for measuring heaviness, but for easy and fast check measurement, fixed weights were decided to use. Another properly calibrated and certified vibro-well was used to check the calibration performance/accuracy.

Before testing, validation measurements of the fixed weight were performed between beam balance and the commercial vibro-well to determine the actual weight of the weights. The assumed actual weight of the fixed weight was initially checked with beam balance and the frequency response was measured with the commercial vibro-well. The measurement of the reference devices against the developed measurement device was then performed and the results were analyzed and presented.

For the static test, the frequency response graphs over time were also plotted for analysis. The test object was the properly calibrated and certified vibro-well. Initialized prediction was around ten Hz range and the test was performed at frequency ranges from 1 Hz to 50 Hz iteratively. And again, the frequency response points were analyzed and compared with initial guess prediction, optimized RF, and the state of the measuring device. Higher measuring performance with a decent settling time and good down-sample ratios, and with overall measurement accuracy were obtained. The static test results were successfully validated by the commercial device measurement and required further calibration for final fit. [27][28]

5. Materials Used in Manufacturing

A sugar measurement device primarily consists of four types of materials: mechanical components, sensors, transmission devices, and electronic control components. Mechanical components, which form the device body, provide support and protection to the components. They must possess properties including not easy to deform, not easy to rust, fixed connections, and good machining performance. Common materials for mechanical components include carbon steel, cast iron, aluminum, and special engineering plastics.

The sensors of the sugar measurement device include a thermometer, pressure sensor, and resistance measurement sensor. A thermometer is a temperature measuring element that detects total vapor pressure temperature. A membrane type pressure sensor converts the pressure of a fluid into an electrical signal output. A resistance measurement sensor has two leads long enough to be easily connected to the test object. Common materials for sensors include various types of steel and temperature-resistant conductive materials. The transmission devices on the sugar measurement device include a diaphragm pump for getting liquid samples and a double-decker circular rotatable table for transferring the sample. Its frame must possess structural strength and rigidity, and corrosion resistance is also desirable. Common materials for transmission devices include acid-resistant stainless steel and composite materials.

An electronic control system is required to control the operation of the sugar measurement device, process measurement data and transmit it to the computer, as well as control the results of the device. It consists of a control box, a PC, and a printer. The main function of the control box is to provide a switching power supply for the unit and controlling other components of the device. A computer is used to process the data from the sensor and conduct experimental analyses. If necessary, the computer can also facilitate communication between the device and a movable terminal. The components inside the control box, including a single board computer, a switching power supply, data collector, relay switch, and other relevant units, typically require specific circuits mounted on an industrial motherboard. Common materials for electronic control components include various types of memory chips, metal coating, ceramic materials, and polymers. [4][29]

5.1. Types of Materials

In the domain of sugar measurement devices, the choice of construction materials is pivotal in determining their performance, longevity, and accuracy. Various components are essential for the successful operation of these devices. A remarkable range of materials is available for the formation of these components: metals, polymers, ceramics, glass, and even biomaterials. Each of these materials has its own sub-group of material families, making the selection of shape and form of a component rather complex. The materials used in the manufacture of sugar measurement devices can be broadly categorized into metals and alloys, polymers, ceramics, composites, glass, crystal, and biomaterials.

The most widely employed metals in the manufacture of sugar measurement devices are stainless steel, zinc, aluminum, brass, and copper. Stainless steel, particularly 304 grade, is highly resistant to corrosion and is validated in food processing applications. Moreover, it is highly durable, which enables the manufacture of intricate components such as springs, pinions, and blocks. The drawback of stainless steel is that 316-grade stainless steel must be employed in high-performance applications. Zinc alloys are extensively used in the production of die-cast components. For light-weight applications, die-cast aluminum is used for manufacturing components such as housing enclosures. Brass components, although they have low corrosion resistance and are not ergonomically sculpted, remain a favorite option owing to their affordability.

Plastics acquiring prime focus in manufacturing sugar measurement devices are polycarbonate, polyoxymethylene, acrylonitrile butadiene styrene, and polystyrene. Polycarbonate, while available only in sheets, is transparent, has good thermal resistance, and is highly impact-proof. However, polycarbonate is not UV resistant and tends to yellow after prolonged exposure. Polyoxymethylene is relatively more resistant to UV, but yellowing occurs above a certain temperature. Polyoxymethylene, while moderately durable, is susceptible to wear and thus is not ideal for manufacturing components such as supports. However, polyoxymethylene is favorably used for manufacturing capacitive measurements. Acrylonitrile butadiene styrene is an economical alternative to polycarbonate, though less optically clear. Acrylonitrile butadiene styrene, while not as impact-proof as polycarbonate, gives a decent impact-resistance. Polystyrene, on the other hand, is a highly transparent but brittle polymer that is usually used for low-cost components such as top lids. [30][31][32]

5.2. Material Properties

The preparation of samples of sugar solutions with well-defined properties (temperature, refractive index, density, viscosity) is an important aspect of the development of sugar measurement devices. This is especially required during the characterization of lab-on-a-chip (LOC) devices, before the first measurement is made with test solutions. The sugar concentration can vary from 1 to 67% by mass or 0.1 to 72% by volume with temperature-dependent viscosity values reaching non-Newtonian high levels of approx. 80 mPa s at a concentration of 66 Bx/64 °Brix. The density and the refractive index are both non-linear functions of concentration and temperature. A general overview of the material properties of sugar solutions (properties not measured during the measurement, b), their relation to industry and inclination towards lab-on-a-chip (LOC) as a new measurement approach with defined fluid properties is provided along with their importance as a quality control tool [1]. A literature search for measurement methods of the properties of sugar solutions was performed and gaps in the literature regarding temperature-dependent density and viscosity measurements of sugar solutions can be seen. New measurement systems have been developed for the measurement of sugar solutions based on widely available consumer technology. Based on a soundcard and , tests are presented of a refractometer using a single plastic lens and a simple voltage divider for the angle of minimum reflection. As an easy and inexpensive method to measure the temperature-dependent viscosity of sugar solutions and allow for the determination of matching temperature-density pairs, a small oscillating pen with a microcontroller board has recently been developed alongside a general software package to operate and calibrate it. As a first step in the hands-on manufacture of comparable LOC devices, a very compact measurement setup with two separate temperature zones, and off-the-shelf 3D-printed components, has become commercially available. Advantages of a setup employing acoustic resonators using widely available MEMS crystal oscillators and commercial micro-heaters with up to 2d100 mm chips are also discussed.

5.3. Sourcing and Supply Chain

Most of the materials used in manufacturing measurement devices are readily available in the market. However, there are some proprietary components, especially key electrical components, which would need to be sourced from select vendors. The experts in this project would contact these vendors and procure the required materials for prototyping. Some components can be 3D printed and may take a week or two extra to arrive for the design to show up. Nevertheless, there are alternative materials that can be 3D printed that may allow the design to show up before the key electrical components arrive. The most susceptible delay is expected by the electrical components which include two sensors and one display IC and associated components that are available from only two or three vendors.

The ideal supply chain would involve proven technical resources who can supply tested boards with guaranteed quality and performance. In-house prototyping usually entails misunderstanding in designs, mutual biases in understanding, prototype and testing delays. A good alternative is having a modular design with well-defined interfaces between the components allowing boards of different sources to be integrated effectively. With this approach, a robust prototyping and supply chain can be built that can prematurely manufacture an accurate Sugar Measurement Device. By blending with in-house design expertise, the gaps in knowledge on the approaches to use, specifications to choose, accuracy and reliability concerns can be bridged. A chosen component would have to be tested rigorously with suitable models to understand its performance limits and attain the desired margin of safety.

The targeted expected new designs would have fewer vendors than the available number of vendors. Nevertheless, while these vendors have the experience, expectation and readiness to manufacture the designs, vendor negotiations usually can stretch into long discussions and tie up the management resources which might be unproductive to the vendors. An ideal end-to-end supply chain must have either in-house capability to quickly modify adaptations of existing products to new leads or resource/design houses that would iterate several cycles of modifications to obtain designs close to the requirement. [33][34][35]

6. Manufacturing Techniques

Manufacturing can produce sugar measurement devices using various techniques, including injection molding, CNC machining, and 3D printing. The particular manufacturing technique used will be determined not just by the cost involved in the manufacturing process, but also by the tolerance of the product, the timing for the manufacture, and batch availability. Injection molding is usually used for plastic parts; the processes may produce mass amounts if flip chips. CNC machining is usually utilized if the product's geometry is complex. 3D printing is common for prototyping, small batch production, and adding complex internal features.

A common manufacturing technique of sugar measurement devices is injection molding. A large composite is heated enough to melt it and enable its action to run through heated barrels with both heaters and a screw gear that turns it forward. At the end of the barrel, there is an injection nozzle and heat injector. The melting time through the mechanic action is gained by the heater, ready to be injected into the mold through the nozzle. The screw gear is positioned at the end of the melting barrel while the mold is assembled. Ejector pins push the finished product once solidified, and the mold is opened. A CNC machine complements injection-molded parts used for sugar measurement devices.

A CNC machined electronic housing involves a turning process first; a tense is made to keep the part fixed for good finishing. For the second part, it will be machined for the display place and parts of installation. After these steps, it will be wire cut to fit the plastic part with transferring machine-made holding parts. The surface will be sanded because of the grave surface in the machining process. 3D printing is a commonly used manufacturing technique as well. Sugar measurement devices with a 3D-printed housing consist of three components: a screw (center part), the outer shell (bottom part), and mounting plates. The connection between the shell and the screw is achieved with a combination of a stud and a hole with a slight slope. A protrusion on the screw is mated with a hollow on the mounting plate, upon which the electronic board is stationed at the bottom.

6.1. Injection Molding

When operating an injection molding machine, several settings must be selected to produce parts successfully. Each of these settings affects the end quality of the part in different ways [36]. The key variables identified are melt temperature, mold temperature, injection screw speed, packing pressure, packing/cooling time, clamping force, and shot size. Oftentimes, one variable needs to be studied across multiple values to evaluate the effect, so it is standard to refer to each variable as a “factor” and the extent of one iteration as a “level.” Effect sagging and over packing cause part ejection difficulties and directly result in scrap parts due to handling issues or high discrepancies. Sagging increases the distance from the injection point to the ejection point and reduces the ejection speed. Some resins absorb moisture while sitting in lower temperature molds and are not suitable for hot mold applications. Increased clamping force also generates greater stress on mold supports and the casting body.

The process whereby hot, viscous plastic is injected into a cooled metal mold is a complex and non-linear molding process. Modifications to the design or the setting of the existing design will affect the storage system volume and time through which it fills the part, which may affect the final shape and material quality of the part. In order to produce parts that meet specifications, all the settings must be specified correctly. Mongrel or poorly manufactured molds may not meet specifications either and must be worked on to resolve the issues. In this molding operation, the Process Window variables were modified to explore their relationships to one another. The relationships of the process variables can be delimited at the desired best quality and lowest cycle time. Cycle time study focuses on the change of process variables in order to find objectives that best produce the parts. The 3 primary Process Window Variables selected are the melt temperature, mold temperature, and packing pressure. All the settings must be selected to allow complete filling and proper packing of the part. However, each variable affects the filling and packing of the mold in a different way.

6.2. CNC Machining

The use of CNC machining has made a great impact on the industry. With the automatic operation of machines based on a computer program, CNC machining obviates most of the manual work that used to be required of an operator. This makes the CNC machining of sugar measurement devices a convenient way of obtaining high-accuracy parts quickly and efficiently.

CNC machining generally uses pre-made files for the design of a part that needs to be manufactured. A set of coded instructions is written to ultimately produce motion instructions for machines. The files are loaded into the CNC machine for the machining process to take place. However, in the context of manufacturing sugar measurement devices, there is an existing rigid design. The challenge now then is how to transfer this design into a format first. The use of scanner technology would be a laborious way to achieve this. Instead, the design of the sugar measurement devices is sensed using design software. The sensed design is then imported into another software for refinement and conversion into a file format.

Using the ready-made file, the creation of machine tool paths is possible directly in the CNC machining software. The tool paths are then outputted as code for the CNC machine to read. With the loaded code, the CNC machine will be able to operate and produce the finished part of the sugar measurement device. The finished sugar measurement device is coated using a CNC machine, a first of its kind in Asia. [37][2]

6.3. 3D Printing

This method is a new automated implementation of the accurate total sugar content meter QATR 5 SSM. It has multiple advantages over traditional mechanical based sugar content meters. It takes around 5 minutes to display the results. It has a small footprint and is portable.

This device was tested with Liquid Su-G 7.0 and Liquid Su-G 25.0 on Food & Beverage Sugar SS and Food & Beverage Sugar CS Cup/Grams. This test was conducted at a standard temperature of 23 ± 1 °C with controlled winds and humidity. Each sample was used three times and the displayed results were completely connected. The relative error was 0.0% so the results were accepted. Two of these devices, one for lab and the other for manufacture plant tests were ordered. It can replace slowly and bulky mechanical sugar content meters like the AA29-1 Devices [38].

Its limitations are a min 60 ml liquid level sample volume, which is too much for large part of packages/ containers, and the need of choosing medium holding container for each new liquid, and calibrating/replacing the 35% sugar content reference solution for each liquid. Currently it cannot determine sugar content for mixed or unknown liquid. These shortcomings can be overcome with a camera based proven algorithm and an optical waveguide based integrated sugar detector to determine sugar type and content. With cold transmittance based measurement of the reaction heat, a new method can be used to measure multiple liquid components.

7. Quality Control Measures

Recently pointed out the need for an organized effort to approach quality control in consumer glucometer devices. Analysis of some consumer glucometers pointed out serious deficiencies: markers present in given samples were not detected in some consumer glucometers for one product and erroneously detected for two others; and studied the glucometers' robustness against temperature, humidity and submersion. Testing systems were developed for glucose measurement by [39], and consumer glucometers' test protocols have been publicly investigated since 2017. This work can be used as a reference for specifying requirements of raw materials and suction electrodes to be absorbed in devices that are destined for sales. Still, no quality control devices aimed to consumer glucometer devices has been published.

On the other hand, sugar testing is a common task for many production facilities. As a chemical ingredient, sugar is utilized in a large number of food production facilities as well as beverages, and qualitative and/or quantitative analysis of sugar is thoroughly conducted at the site before processing. Testing devices designed for use in production facilities utilize various methods, which include a refractometer, a polarimeter, a proxy-based sugar test device, and a titration device, among the others. pointed out the inconveniences of testing sugar at production facilities with the current method. Industry experts prefer to measure new raw sugar before processing at the site, and production facilities with high sugar content in the beverage create a high-risk working environment.

In this paper, the design and development of QoSugar: a sugar measurement devices with an attached calibration and data-recording application will be described. The optical sugar measurement method was utilized, and the entire mechanism for measurement and filtration was designed to keep the device size at the high utility peripheral area, and sampling and data recording was made user-friendly with an accompanying interactive application. Accurate calibration was achieved by storing data for two wavelengths with one optical path. The device was aimed to be commercially viable in both the farm and production facility scenarios.

7.1. Quality Assurance Protocols

The aim of the quality assurance protocols during the design stage of a glucose measurement device was to ensure that quality characteristics affecting safety were identified and appropriate requirements captured in the specifications. A quality and risk management file was created that detailed the quality assurance protocols for each stage of the design process. Each stage involved the identification of quality characteristics and the formulation of protocols that were targeted to ensure that the quality characteristic of a glucose measurement device.

Each protocol detailed the quality characteristic, ensured that the requirement/specification was measurable, and set out appropriate procedures for testing or measuring the product against the requirement/specification. Many of the protocols involved a comprehensive stepwise procedure for design processes addressing conformity assessment. To ensure the effective implementation of the quality protocols, risk management support was essential that involved the identification of responsible parties, timelines, documentation requirements, and preventive/corrective actions. Quantitative metrics were established to support quality resonance in a similar fashion to KPIS and QIs.

Incorporating Six Sigma metrics was effective because it involved the identification of sources of measured data and mapping of measures to each step in the quality protocols. Process capability quantifying sigma performance was appropriate because most of the stages had fixed processes of varying degrees of operator control. Measurement data were managed in a measuring and monitoring data management system that ensured transparency, security, and traceability. IT security protocols were established, detailed, and implemented ensuring protection and traceability. Audit procedures and evaluation against defined performance metrics were built in to ensure transparency and accountability [39].

7.2. Testing Procedures

The completed sugar measurement devices require thorough testing procedures to ensure optimal performance. These procedures involve a series of tests designed to evaluate different aspects of the device's functionality, accuracy, and reliability. Although the testing outlined here can be used to verify basic functionality and performance, it should be noted that some of the tests require exact weights of sugar and water that are not practical for the average user or consumer in a home or restaurant. Alternative tests will also be outlined for users who desire a more practical means of verifying device performance.

Cascaded testing: The sugar measurement will read out the weight, and the device will feed out a small amount of sugar. The device will continue feeding out the sugar and measuring until it totals the pre-set amount. The total weight is displayed initially as the first display, and this will change to the current weight fed out by the subsequent feeds. The display will reset to zero when the accumulated weight reaches the pre-set amount. To evaluate the success of the test, both displays need to read exactly wrong. As a secondary measure, if this is implemented, the sugar measurement devices should count how many feeds of sugar have been given. A graphical depiction of feeds taken can be displayed, which will increase by 1 each time there is a successive feed until the accumulated weight reads equal to the preset amount. If the display resets to zero and the graphical representation stops counting at this point, the sugar measurement system has passed the most rigorous test.

Millisecond timing: The speed that the sugar dispensing apparatus moves is another crucial element of sugar dispensing. This can be verified by pre-setting an amount of sugar to be dispensed and running the sugar measurement device to determine what the amount that is, in units of time elapsed. The actual and expected results can be used to determine if the feeder is too slow, too fast, or nearly correct.

8. Regulatory Compliance

Manufacturers of sugar measurement devices must comply with national and international standards and regulations. Compliance with industry standards ensures that the devices are safe, accurate, and reliable. Compliance with safety regulations helps to minimize the risk of accidents and injuries associated with the use of the devices. Manufacturers must stay up to date with the latest standards and regulations, and actively participate in the development of new standards and regulations. As simple and robust instruments used in the sugar industry, devices used for sugar measurement should be designed and manufactured in accordance with applicable consumer safety regulations in the manufacture country. Careful consideration should be given to the conditions for which a device is manufactured in order to comply with safety regulations. Some wording of specific clauses in regulation standards leave room for interpretation and hence manufacturers must decide for themselves whether a device should comply with a general regulation or whether a higher specific requirement must be satisfied. Where a device must meet specific national regulations in non-EU countries, manufacturers can ask an accredited body for advice. The aim of this is to ensure that consumers have sufficient safety from an acceptable point of view. Testing of a device and a testing report will be required for registration if it has to comply with safety regulations. Manufacturers of sugar measurement devices must comply with industry standards. Industry standards specify the minimum requirements for accuracy, precision, and reliability of sugar measurement devices. Compliance with industry standards ensures that the devices can provide accurate and reliable measurements of sugar content. Manufacturers must comply with standards as it applies to a device. Compliance with standards outside the manufacture country, regardless of market size in the country, is also essential. If the market for a device is large enough and no reasonable prospect can be shown that an owner would not manufacture a device compliant to a standard, the owner should comply with the standard and perform annual checks of devices in service. If there are only few devices on the market, the owner is free to act in accordance with safety standards needed to keep risk and liability cost to an acceptable level. In both cases, there might be some offers for compliance testing by assessment bodies. [40][41] [40][42]

8.1. Industry Standards

The demand for sugar and its derivatives continues to rise and is expected to grow significantly. In Syria, security and energy challenges have made it difficult to manufacture high-quality sugar measurement devices. These devices measure the quantity of sugar by measuring the mass, volume, brix degrees or impurity percentages, or a combination of these measures. A new design was created to meet the market demand for simple, cost-effective and high-performance devices, but without using imported components, which add to the production cost.

Various sugar measurement devices are available, but some are either complicated or expensive. This research project is an attempt to manufacture medium-level, Arabic reader, sugar measurement devices locally in Syria. During the research period, the designs of the systems, the sensors and circuit components have been constructed and the devices are manufactured and tested. The devices provided very accurate measurement for the sugar quantity. The new design includes sugar mass measurement device, gear volume measurement device, sugar brix degree measurement device and impurity percentage measurement device. The design presented in this project report has laid out the development and manufacture of sugar mass measuring gauge to meet the demands of manufacturing these devices locally.

Mass: mass may be measured using a PC computer and a load cell. The load cell has come mass with a support and a variable resistor. This mass was first felt by the support and the load cell converts it into a voltage which is fed to the PC with an A-D converter. The PC computer runs an approved algorithm to display the mass. Either barley flake mass or sugar mass display may be selected to be monitored plus the date and time indications. The indication extends into display zero pixel digit and on/off preview for performance monitoring.

Volume: volume may be measured using the manually controlled gear hall and one of the above-mentioned pressure sensors. Inspector ingenuity manually sets up the hall, connects the pressure and matches the beakers. The volume or flow rate may be read from the OS window. The existing high-value pressure gear assembly is utilized, but plans for constructing new gear assembly are included.

Brix: brix temperature acquisition units of the simplest kind are built using a thermistor, butter record, an array of condensing diodes, a log amplifier, multiply one and filter board. The current brix degree indication is displayed on the OS screen as a 2-digit digit along with date and time indications. A buzzer notify should be generated whenever the degree of brix falls below some limit.

Impurity Percentage: this device measures the reflection ratio of a laser beam punched through sugar crystals. It is based on a reverse voltage integration of a photodetector. The current corresponding to the reflection is computed internally by a mini computer which outputs the density value on a 5-digit digit. The device consists of a laser transceiver with a 360-degree rotating channel and a sugar holder. It has been successfully tested and worked when not exposed to direct sunlight and the sugar crystal arranged compactly when the reflecting surface is at an optimal angle to the direct one.

8.2. Safety Regulations

Much like the reliability of most measurement techniques, the safety of designs is often neglected or poorly executed. Nearly all the individual components used in devices based on transmission principles and many components used in volumetric systems have inherent hazards. If any of those hazards were not understood during the design cycle, they could result in fatal consequences. Good designers follow a logical, easily understandable design process to help them capture and manipulate their ideas without omitting important information. The successful analysis, design, and presentation of a safe measurement device are often difficult to achieve and require the cooperation of several designers.

Safety should always be a priority when designing any new measurement device. A qualified engineer must check all designs carefully before being built. Safety devices or redundancies must be implemented if there are any hazards that cannot be eliminated from designs. However, designing such safety regulations is sometimes difficult, as possible hazards could render the device incapable of measuring any sugar reliably. Sensor choice is particularly critical, as all sensors have some inherent danger and often require extra circuitry to make measurements safe. If sensors are carefully chosen during the design cycle, there should be no marketable designs that are inherently hazardous after being built.

Before any designs are built or prototypes are constructed, it is advisable to publish drawings of all components, including all dimensions, materials, and industry standards of all parts, in a venue where any manufacturer will be able to view them. All manufacturers must have a good understanding of analytical devices and be able to rely on their own safety regulations and procedures. Ideally, manufacturers will be licensed by an external oversight body to ensure they understand the importance of safety regulations and know how to comply with them. This is all made more difficult by the fact that such a manufacturer would very likely have the final say on any safety regulations or redundant designs put on any devices. [43][44]

9. Cost Analysis and Pricing Strategy

To estimate productive costs within a three-year period for a sugar content measurement device manufacturing industry, several aspects need to be taken into account, including initial investment costs, raw material costs, labor costs, production overhead costs, and selling/marketing expenses. Initial investment costs encompass fixed assets such as machines, workplaces, and tools. Meanwhile, pricing strategies for products can be determined through markup pricing, where prices are set on a markup percentage basis from the product cost. For a markup of 30% of product cost, selling prices are in the range of IDR 3.300.000,00 - IDR 4.970.500,00, based on a product cost of IDR 2.540.000,00 - IDR 3.816.900,00. This preliminary study estimates that the sugar measurement devices manufacturing industry is feasible if it has a minimum level of sales of 3-4 products every month.

Industry KAPASS is an industry engaged in the manufacture of sugar content measurement devices with sensing acetate, fighter switches, and LCD or LED display windows. The utilization of measurement devices is feasible in terms of cost. There are no limitations on the production targets of the kazi measurement devices, price suitability, and device quality, as evidenced by conducting sugar measurements in both industrial laboratories and home industries. Potential consumers of KAPASS devices include sugar granule manufacturers and other producers who create sugar products or processed sugar [45].

Despite the absence of similar products in the market, it is possible to manufacture measurement devices with sensing acetate, fighter switches, and LCD or LED display windows with an estimated upscale price of ± USD 300 standard. The estimated production capacity of the sugar content measurement device industry is ± 60 units/month at ± 25% capacity during the first six months of operation. Raw material supply is sufficient, with a steady supply available for ± 1km away from production sites. Labor wages are economically feasible, and marketed prices are sufficiently high, providing a margin of ± 43%-66% from product costs. Based on a margin of 50% from the product cost, the estimation of sugar content measurement device price is ± USD 478 product/unit, feasibly paid by granule sugar manufacturers with larger revenues.

9.1. Cost Breakdown

There are three types of costs, which are a fixed cost, a variable cost, and a total cost. The cost structure of the sugar measurement device project is summarised. The total cost is designed for the first three years of production. It consists of the fixed costs and variable costs. The fixed costs include laboratory instruments, production equipment, after-sale equipment, machines, office equipment, computer equipment, renting fees, staff wages, insurance, and salaries of employees. The variable costs consist of production material, packaging material, transportation, product warranty, and sales commissions. There was no fixed cost for office equipment and computer equipment in the first year since the university already has such equipment, and no transportation fee was paid for the first year either in the university show booth exhibit.

Fixed Costs

Laboratory instruments were purchased such as laboratory scales, spectrophotometers, and polarimeters for making and testing prototypes, total 5000. Some production equipment, including a drill press, toolbox, measuring jugs, etc., was also bought for prototypes and production construction, and total 3500. The after-sale equipment consists of tools for diagnosis and fixing plastic and circuit-related problems, and the total cost is 2200. A soldering iron and hot air welding machine were purchased for manufacturing the communication module, and cost about 500. A laptop and desktop computer were also bought for research and development and post-sale service. Each cost 700 and 400, respectively. Office equipment and furniture were not purchased in the first year since it is already in the office. This consisted of a desk, cabinets, conference tables, chairs, and so on, which cost a total of 2400. The open-space area with about 20 desks was rented for the business and post-sale service meeting. The rental fee cost 1000 per month, a total of 12000 for the first year, with a 2% annual increment for the next two years. After all, the sum of fixed costs for production is 92900. A total of 6 salespeople are needed with different monthly wages. Sales representative, technical support, automation Engineer, technical manager, sales manager, and technicians cost 1850, 1650, 1500, 2500, 4000, and 1300 respectively per month. Under a 10% on-cost, the total wages of staff are 71890, 79000 with a 10% annual increment, and 8% for the next year accordingly. Insurance consists of industrial accident insurance, commercial insurance, etc. The total insurance premium for the first year is 3000, with an annual increment of 2%. The sum of total fixed costs is 552040.

Variable Costs

The ToF-Sims needs chemical reagents which cost about 10000. The Lab-on-chip also needs chemical and biological reagents, and it costs about 2000. The commercial server costs a 7000 license and the development cost is about 15000 under the 10% annual increment of yearly support fee. Packaging LDL and HDL discs into a box cost about 100000 each production which includes box, test tubes, and labelling. Each set would be fraud abroad automatically with the due cost of 200. The substitute back vehicle was purchased round 5000. Each product costs about 500000, under a 10% on-cost with an increment of 8% annually. These costs would sum as 930000 in the first year, 1662000 in the second year, and then 566000 in the third year. [46][47]

9.2. Pricing Models

Production of measurement devices incurs fixed, variable, and ongoing costs that can be used to create pricing models. Analyzing Unit Economics or Customer Lifetime Value helps estimate Revenue and Profit margins. Profit Margin analysis examines Profit on both a whole device and per test basis for the three device configurations. Estimation of Cost and Pricing models on Type of Devices or Pricing Per Test Basis can be created. Finally, Outcomes of Cost Analysis, Pricing Model Outputs, and Profit Calculations will be presented.

Pricing Models are based on fixed and variable costs brought over from the Cost Analysis with the assumption that future ongoing costs will reduce as manufacturing processes are optimized. One model estimates Revenue and Cost of Unit Economics while another estimates Revenue and Profit margins by addressing Customer Lifetime Value with assumptions of Repeat Test Over a Time Period, Instant Tests, Customer Lifetime Value, New Customer Acquisition Cost, and Monthly Profit. Additionally, Profit Margin analysis is conducted for both Whole Device and Per Test Basis at minimum and maximum pricing of Devices or Pricing Test Basis.

Whole device profit margins range from 165.8% to 217.5% for Prototype, 42.8% to 96.8% for Basic and Advanced devices, respectively, while per test profit margins range from 71% to 338% for Prototype, 9% to 56% for Basic device, and 36% to 143% for Advanced type of devices. This analysis is based on selling any of the device configurations at Minimum Price, assuming devices are sold outright and Unlimited Tests are bought for testing. The Super Cutting Edge Premium Pricing models and Premium Pricing Device Models provide the most Profit margins and can be pursued later, as the company ramps up to 10-15 devices manufactured per month.

10. Marketing Strategies

To successfully market the sugar measurement devices, a mix of online and offline strategies will be employed, incorporating modern digital tools, collaborative partnerships, and traditional expos. Digital marketing strategies will focus on social media marketing, search engine optimization, search engine marketing, content marketing, and email marketing. Given the ability to connect with manufacturers, suppliers, retailers, and wholesalers, a business account will be created, and regular engaging posts relevant to sugar processing will be shared. Instagram may also be leveraged due to its visual-centric nature, as it can showcase images of the devices and sugar factories to attract visual interest. Facebook will be utilized to enhance channels for potential customers, frequently posting relevant content focused on sugar and measurement technologies. SEO will improve website visibility by allowing it to rank higher on search engines, thus increasing the likelihood of attracting customers searching for sugar measurement devices. This will be implemented by selecting keywords relevant to sugar measurements and optimizing website content with these keywords, including titles and body text. SEM will involve using ads to target potential customers based on their search queries. Content marketing will include creating relevant and informative articles and videos about sugar measurement devices. Hosting webinars can also enhance brand visibility. Email marketing will create an email list of all clients, including new leads and clients attending trade shows, sending monthly newsletters about the company. Attendance at trade shows and expos will be a key strategy, ensuring participation in events focusing on sugar mills and measurements. An eye-catching booth design, highlighting expertise and value to potential customers, will attract attendees, along with a demo setup of a sugar measurement device. Brochures will detail device specifications and how they can solve problems, providing potential customers with the option of scheduling a demo. Trade shows present an opportunity to ask questions about the devices and learn more about them, with a targeted audience likely to seek measurement and quality control devices. Lastly, proactive outreach to companies involved in sugar production for possible partnerships and collaborations will be implemented. This will include sugar manufacturers, suppliers, and industrial measurement devices manufacturers. For sugar manufacturers and suppliers, the relevance of measurement devices will be discussed, and the ability for the sugar supplier company to be an exclusive distributor of the measurement devices in partnership with the manufacturer company will be proposed. A collaboration with an industrial measurement devices manufacturer could involve proposing a joint venture in the manufacturing company for the distribution and sale of quality control devices focusing on sugar processes. With a strategic combination of these approaches, business growth will be ensured, enhance potential customers' awareness, and improve company branding. [48][49]

10.1. Digital Marketing

Digital Marketing is one of the most effective strategies used in marketing these days in comparison with other marketing strategies. There are several social media platforms where promotional posts regarding Digital Marketing can be shared. Besides that, there are numerous websites and applications where advertisements related to Digital Marketing can be shared. Irrespective of the Business Size, all kinds of Businesses like Small, Middle, or Big can adopt Digital Marketing as one of the Strategies to attract customers.

Like every other product, Digital Marketing is wildly applicable for the Sugar Measurement Devices which can be posted on Social Media Platforms and Websites and Applications. Through the promotions and advertisements about the Product on the Internet, it can reach customers easily and it can also be purchased in different countries around the globe. If done properly, Digital Marketing can even make a Torch and Egg into a Hit Product. The targeted customers can purchase the Sugar Measurement Devices through Online Payment and can get it delivered to their doorsteps. Customers can also give reviews about the purchase on the Internet which further increases the reach of Digital Marketing. Digital Marketing is one of the revolutionary innovations in the Marketing Strategies of Products.

Some of the advantages of this strategy are given below:

- Wider Reach: Digital marketing has reduced the boundary limitations in selling the product. With Digital Marketing, a Business can market its Sugar Measurement Devices to Customers Around Globe. - Engaging Content: As Digital Marketing is used through modern technologies, it allows use of engaging content which traditional marketing cannot provide. A good engaging content always attracts people. - Cost-effective: Advertising through traditional media is comparatively Costlier than Advertising through Websites or Social Media Platforms, and Online Promotion. Expenditure like standing fee and renting is also avoided in Online Promotions. Businesses of any Size can do Digital Marketing easily. - 24/7 Marketing: Advertisements and Promotions about the Product can be posted on Social Media or Websites to spread and promote them which would run 24 hours and can be accessed anytime unlike Traditional Marketing.

10.2. Trade Shows and Expos

Trade shows and expos are another important avenue for marketing sugar measurement devices and generating leads for potential business. Industry professionals gather at these events to showcase the latest technology, machinery, equipment, and building approaches. Some expos also focus on specific fields of the sugar manufacturing process. Although such events are often costly to exhibit at, the opportunity to showcase new and innovative technology and demonstrate how to use it is invaluable. Obtaining a premium booth location on the show floor will result in the best exposure during the event. In addition, it is essential to have personnel on-site who are excited to engage with potential customers and tell them about the products. Attendees appreciate when vendors take the time to show an interest in their business. Prior to any trade show, the company is introduced to a wide range of prospects. These attendees often come to the show with particular questions or needs in mind and are more likely to positively engage with the vendor. However, garnering the attention of attendees who may not be prospective clients can also pose a challenge. The company should purchase attendee list rentals, along with miscellaneous lists such as those for non-profits, local businesses, or businesses near the convention, to solicit people who may not be directly related to the industry. It is important to note, however, that incorporating prizes into any promotional list can detract interest from the business itself. Providing a simple prize will draw ticket holders into the booth; however, attendees remain interested only for the prize announcement and are unlikely to return for further discussion or consideration. A unique prize that relates closely to the business itself could promote greater engagement and give attendees an immediate reason to remain at the booth.

Although trade shows often occupy less than half a week per year, tens of millions are spent each year on exhibiting at these shows. Trade shows are global and operate in nearly every country in the world. While attending a trade show is promising, it is also very risky. The average show costs around forty-five thousand to fifty thousand dollars, and many can run up to double this amount. On the other hand, some companies exhibit in order to share total expenses on a booth with a well-known company, which brings their presence to the show. It is important to analyze both the cost and value of shows. This requires a year-to-date sales projection, the current capacity to expand, and the question of how or if expansion will be allotted to new clientele. The investment in time and money for shows should yield well in new clientele or return on money spent within the year.

Trade show attendance can be a corporate or personal decision, and hopefully ties to a company's personnel structure. Building a presence in the minds of the clientele is important, but more important is building a bond with attendees who carry the responsibility of buying and purchasing equipment. The first step is to identify major and minor shows. Attending shows in which competitors and trends will also be present may seem counterintuitive, but it is crucial to predict the industry direction. From this perspective, building rapport with colleagues is vital. From major shows around the world, attendance can be narrowed down to target regions and industries. [50][51]

10.3. Partnerships and Collaborations

For our organization to market the sugar measurement devices successfully, strategic partnerships and collaborations with firms that have extensive knowledge and experience in marketing measurement devices to sugar manufacturers will be pursued. Such partnerships are crucial for growing a base of customers, as they expand the organization's outreach through established networks. This marketing strategy will involve conducting research to identify potential partners, reach out to them, and leverage those relationships to create greater awareness of the sugar measurement devices. Partnerships and collaborations with firms that understand the sugar measurement devices target market and already possess a customer base are vital for increasing the device's exposure and accessibility. These firms will have established marketing channels with the businesses, divisions, or departments responsible for the devices, thus creating greater visibility for the product and increasing sales. In terms of making the product readily accessible to those consumers, firms with extensive background knowledge will be able to ensure the devices are sufficiently stocked and, should there be any concerns or questions, they are equipped to provide the necessary support. Pursuing strategic partnerships and collaborations with such firms is the first part of the marketing plan. Initially, potential partners can be found through academic journals, trade organizations, trade shows, sugar manufacturer directories, and trade publications. Those that are largely based in Canada and the US will be prioritized, as those are key markets for the marketing strategy. Once potential partners are identified, contact will be made via email to introduce the organization and its devices, and to express interest in talking further. The email will highlight how the partnership would be beneficial for both firms, thus increasing the likelihood of securing a meeting. Should that meeting be arranged, the goal will be to discuss potential partnership ideas in greater detail. These may include co-hosting webinars and attending trade shows together. [52][53]

11. Conclusion

The manufacturing of sugar measurement devices is a complex and multifaceted process that requires careful attention to detail and precision engineering. Sugar measurement devices play a crucial role in the sugar industry, accurately measuring the concentration of sugar in various solutions. This information is vital for ensuring the consistency and quality of sugar products, as well as for complying with regulatory standards. Modern sugar measurement devices utilize advanced technologies to provide accurate and reliable measurement of sugar concentration. These devices are designed to be easy to use and maintain, with user-friendly interfaces and automatic calibration processes. In conclusion, the manufacturing of sugar measurement devices is a vital aspect of the sugar industry, ensuring that sugar products meet the highest standards of quality and consistency. The continued development and improvement of these devices will help the sugar industry better meet the challenges of the future.

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