

CHAPTER 2 - LITERATURE REVIEW

2.1 Information Regarding Nata De Coco

Nata de coco or coconut gel is a chewy food like jelly and made from the fermentation of coconut water. The mentioned coconut water gels because of the microbial cellulose produced by *Acetobacter xylinum*. *Nata de coco* originates from the Philippines and most commonly sweetened to accompany various kinds of food, such as ice cream, puddings, fruit cocktails, etc. The study of the material (in this case *nata de coco*) is very important to determine the cutting method to be applied to the machine.

2.1.1 Content

Every 100 gram of *nata de coco* contains 67.7% water, 0.2% fat, and many other vitamins and minerals (Black, 2012). This means that the machine must be waterproof since it may be exposed to water.

2.1.2 Texture

Nata de coco is very elastic and spongy. Because of the microbial cellulose, its inside turns into fibers. Therefore, it is not easy to cut or tear apart. The average hardness of *nata de coco* as measured using Lloyd texture analyzer is about 565 gf (Kusumo, 2013). *Nata de coco* can be compressed to a certain level where it can go back to its previous size (elastic deformation). When compressed too much, the water contained inside *nata de coco* will be squeezed out, resulting in plastic deformation (yield point).

2.1.3 Current Technology

Nowadays, the cutting process of *nata de coco* in small scale industries in Indonesia are mostly done by hand manually. The *nata* is cut using a common knife after fermentation and molding process. The production capacity using manual operation is only 12 kg/hour, with non-uniform dimension result. The product cannot get into middle high-class consumer through supermarkets or packaged *nata de coco* industry because of its non-uniformity and not attractive shape. Therefore, the target market of this product is only street vendors with direct sales to the customer. (Putro, et al., 2012)

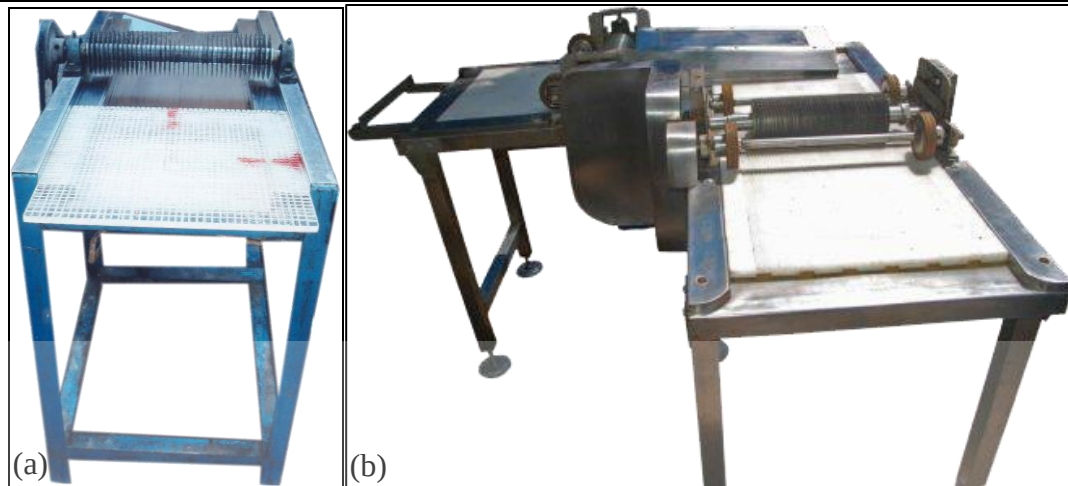


Figure 2.1 – Industry dicer machine with (a) single axis and (b) double axis

In the case of a big industry like *PT. Coco*, a much bigger machine with much more production capacity is necessary. To overcome this problem, machines similar to the figures above are often used. They utilize rotating blades where the nata is passed through below the blades, on top of a board with slits. This method can reach a production capacity of about 120 kg/hour. However, this method is still deemed not useful in the case of *PT. Coco*, since the result is not cubic enough.

2.2 Food Industry Safety Concerns

2.2.1 Hazard Analysis and Critical Control Points

Hazard Analysis and Critical Control Points (HACCP) is a systematic preventive approach for food safety to eliminate any biological, chemical, and physical hazards in production processes that can cause the finished products contaminated. This can be achieved by revising the design of the machine to reduce these risks to a safe level. The principals of HACCP are:

- Conduct a hazard analysis
- Identify critical control points
- Establish critical limits for each critical control point
- Establish critical control point monitoring requirements
- Establish corrective actions
- Establish procedures for ensuring the HACCP system is working as intended
- Establish record keeping procedures

The seven HACCP principles are included in the international standard ISO 22000 FSMS 2005 and must be applied when making the machine for this study since *nata de coco* is categorized as fresh cut fruits and vegetables. (FAO/WHO, 2006)

2.2.2 Food Grade Materials

Materials for the food industry are divided into three categories, food packaging materials, food zone materials, and food contact materials. Food packaging materials are materials that will be used for the packaging of the certain food product, meaning the food will be exposed to the material for a long time (more than a day). Food zone materials are the materials used in machines, actuators, sliders, and any other components that are still in the same zone with the food product without making any contact. Food contact materials are the materials used in equipment, utensils, containers and any other surfaces that are intended to come into contact with food product for shorter than a day.

There are many different regulations about this matter, but the most common and internationally recognized ones are ISO 22000 by International Organization for Standardization, ANSI/NSF 51 by American National Standard/ NSF International Standard, and Regulation (EC) No 1935/2004 by European Community. Here are some articles as listed in ANSI/NSF International Standard 51 – 1997 Food Equipment Materials:

- Stainless steel used in food equipment shall be of a type in the AISI 200 series, AISI 300 series, or AISI 400 series. When used in a food zone, stainless steel shall have a minimum chromium content of 16%. Stainless steel with a chromium content of less than 16% may be used for cutlery, blades, and similar applications requiring a sharp edge provided the alloy has been hardened or tempered by an appropriate post-weld heat treatment process.
- Aluminum alloys, when used in a food zone, shall have one the following Aluminum Association alloy designations or equivalent. For wrought alloys (sheet and extrusion) materials: 1xxx; 3xxx; 4xxx; 5xxx; and 6xxx series alloys. For casting alloys 218.x; 308.0; 319.0; 332.0; 356.0; 360.0; 413.0; B443.0; 514.0; 520.0; 713.0

- Some other material examples allowed in food industry application are: Glass-filled Noryl, Polyphenylene, Fiberglass-Reinforced Thermoplastic, Plexiglass Acrylic, Polystyrenes, Polycarbonates, Vinyl Chloride, Polypropylene, Ryton, Nylon, Glass-filled Polycarbonate Sulfide, Neoprene Compound, Engineered Polymer, Thermoplastics, Copper, Brass, Gold, Silver, Ceramic carbon, Viton Elastomers, Santoprene, EPDM Elastomers, Silicon Carbide, Tungsten Carbide.
- Galvanized materials and other zinc coated materials shall not be used on surfaces intended for direct food contact.
- Paint and other organic coatings shall not be used on surfaces intended for direct contact with food, except where fluoropolymer resin coatings (e.g, polytetrafluoroethylene) are specifically permitted for use under other NSF Standards

2.3 Mechanical Aspects

2.3.1 Cutting Blades

The cutting blades for this process must be sharp enough but also strong, considering minimum size possible. To minimize the cutting force, there are many factors taking effects. The most important ones are the sharpness of the blade, the friction of the blades' sides, hardness and the material itself.

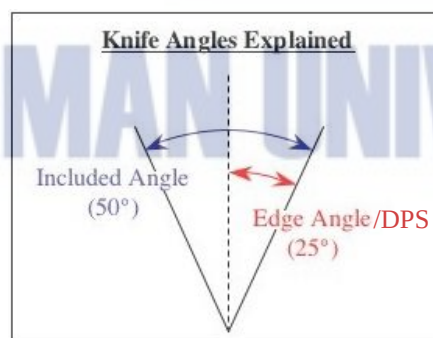


Figure 2.2 – Illustration of knife angles

Very sharp knives are sharpened at about 10 DPS (degrees per side), which implies that the total angle of the knife's edge is 20 degrees. Razors, paring knives, and fillet knives are one of the sharpest blades at an angle of 12° – 18°. Kitchen knives such as utility/slicing knives, chef's knives, boning knives, carving knives, should be around 15° – 25°. Japanese styles are exceptions, where they often sharpened to 14° – 16° depending on the knife maker. Japanese style knives utilize a much harder steel, making

them more brittle than their Western style counterparts. This means care should be taken when handling these knives, as they are more susceptible to chipping and breaking. The sporting knife category, such as pocket knives, survival knives, and hunting knives, experiences more intense action and should be sharpened to the $25^{\circ} - 30^{\circ}$ angle range. The less sharp angle means there is more metal there to cut, thus providing more durability out in the field. For an extremely durable edge, a machete, chisel, drawknife or ax should be sharpened down to $30^{\circ} - 40^{\circ}$, providing even more ruggedness and longer lasting sharpness. (Lee, 1995)

The friction of the blades' sides is depending on the material used for the cutters. The blade of a knife can be made from various materials. The most common are carbon steel, stainless steel, tool steel and alloy steel. The less common materials include cobalt and titanium alloys, ceramics, obsidian, and plastic. Whatever the materials are, the finishing process will also affect a lot of friction of the blades' sides.



Figure 2.3 – Example of Damascus steel blade

The hardness of the material is also one of the main factors, usually stated as a number on the Rockwell C scale (HRC). The Rockwell scale is a hardness scale based on the resistance to indentation of a material. As hardness increases, the blade becomes capable of taking and holding a better edge but is more difficult to sharpen and more brittle (commonly called less "tough"). Laminating a harder steel between a softer one is an expensive process that to some extent gives the benefits of both types (in example Damascus steel from the figure above).

2.3.2 Pneumatic System

To overcome the cutting force and to make the cutting process stable, the most effective actuator for the movement system will be pneumatic (relates to HACCP). The pneumatic system is actuators powered by compressed gas (commonly normal air), through pipe inlets. In a pneumatic system, the most crucial parts are the compressor, the valves, and the cylinders.



Figure 2.4 – MultiPro Expert Air Compressor $\frac{3}{4}$ HP

A compressor is a mechanical device that increases the pressure of a certain gas by reducing its volume. Compressors are similar to pumps, both can increase the pressure on a fluid and both can transfer the fluid through the piping system. The main difference is, gasses are compressible, so the compressor also reduces the volume by storing it in a reservoir tank, while pumps constantly transferring the pressure through the pipes. The compressor that will be used in this thesis is MultiPro Expert Air Compressor with a power capacity of $\frac{3}{4}$ HP.

Pneumatic valves are a mechanical device that can control the flow of the air in the pneumatic system. The most common type is gate valves, where it can close and stop the flow, or open and continue the gas flow. This type of valve also commonly equipped with solenoid actuators, which can be actuated electrically. The combination of these valves can make logics such as AND logic, OR logic, etc. Other than gate valve, there are also check valve (non-return valve), flow control valve (to control the flow rate), and so on. (Mistry, 2013) As a safety measurement, an additional normally closed gate valve must be added to the pneumatic system as a dump valve, where it will “dump” all remaining air in the system when in OFF position. The best position for dump valve is after air source or before actuators. Air can flow into the system and actuators only if the dump valves are in ON position (electrically actuated).

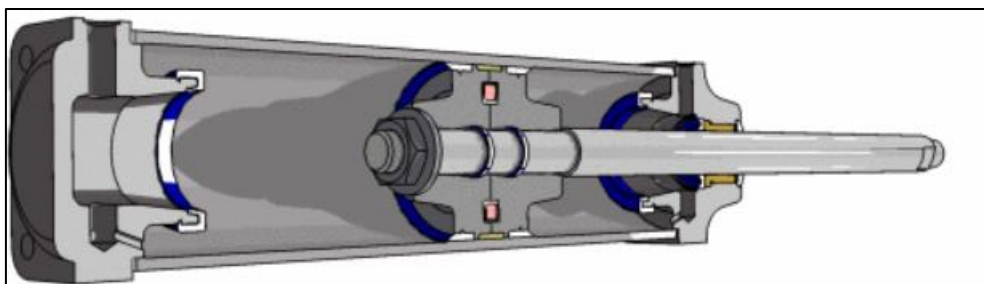


Figure 2.5 – Example of typical pneumatic cylinder

Pneumatic cylinders are mechanical devices that take advantage of compressed air power to produce force in a reciprocating linear motion. Its shape is literally cylinder, with a piston (a disc or cylinder) inside the tube which can be moved back and forth by the force (in this case compressed air), and piston rod to transfer the force outside the cylinder.

2.4 Electrical Aspects

2.4.1 Programmable Logic Controller



Figure 2.6 – Siemens SIMATIC S7-1200 PLC

A programmable logic controller (PLC) is a digital computer used for industrial purpose that has been ruggedized and improved for controlling manufacturing processes, such as assembly lines, robotic devices, etc. PLC has to be used for any activity that requires high-reliability control, ease of programming and process fault diagnosis. A PLC is an example of a "hard" real-time system because output results must be produced in response to input conditions within a very precise limited time, otherwise, unintended operation or malfunction will result. ^[10] For this thesis, Siemens SIMATIC S7-1200 PLC will be used.

2.4.2 Collision Detection

A major problem might happen when a machine works with a production rate as big as *PT. Coco's*. The most crucial problem that might happen is a collision between blade with the clamp or any other part during the cutting process. This condition is very dangerous since it may result in metal particles and/or foreign material, not to mention

big chips, contaminating the *nata de coco*. Therefore, the importance of collision detection is absolute. Collision can be detected through various ways, but this thesis will exploit material conductivity.

Every conductive material has their own coefficient of resistivity and conductivity. Electrical resistivity is an intrinsic property that quantifies how strongly a given material opposes the flow of electric current. A low resistivity indicates a material that readily allows the flow of electric current. Electrical conductivity is the reciprocal of electrical resistivity and measures a material's ability to conduct an electric current. ^[4]

In this case, material conductivity will be the focus.

For comparison, the conductivity of *nata de coco* will be assumed similar as seawater (corresponds to an average salinity of 35 g/kg at 20 °C) which is 4.8 S/m (Kayelaby.npl.co.uk.). In contrary, the other parts which will be made of aluminum or stainless steel (18% chromium/ 8% nickel austenitic stainless steel) will have way much bigger conductivity, with the number of 3.50×10^7 S/m and 1.45×10^6 S/m respectively (Serway, 1998). Therefore, the method will be the blades are made into the open circuit by flowing current throughout the blade then it cuts the *nata*. When exposed to the *nata*, the current will flow with a conductivity of 4.8 S/m. However, when any blade touches any other material with different conductivity, the current will also flow differently. A kind of sensor or meter then can be placed to detect the conductivity difference when a collision occurs.

2.4.3 Dull Blade Detection

During the cutting process, a significant force will be applied to the blade as a form of action – reaction force from the *nata de coco*. Then this force can be measured using a load cell. A load cell is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured. Through a mechanical construction, the force being sensed deforms a strain gauge. The strain gauge measures the deformation (strain) as a change in electrical resistance, which is a measure of the strain and hence the applied forces. A load cell usually consists of four strain gauges in a Wheatstone bridge configuration. Load cells of one strain gauge (quarter bridge) or two strain gauges (half bridge) are also available.^[14] The electrical signal output is typically in the order of a few millivolts and requires amplification by an instrumentation amplifier before it can be used. The output of the transducer can be scaled to calculate the force applied to the transducer.

By measuring the force applied to the blade during cutting process continuously, it can be determined whether the blade is getting dull since the force necessary to cut will increase when the blades have gotten dull. Therefore, an early detection can be done before any occurrence happen (such as actuator overload or broken blades).

2.5 Previous Studies

2.5.1 Conventional Dicer

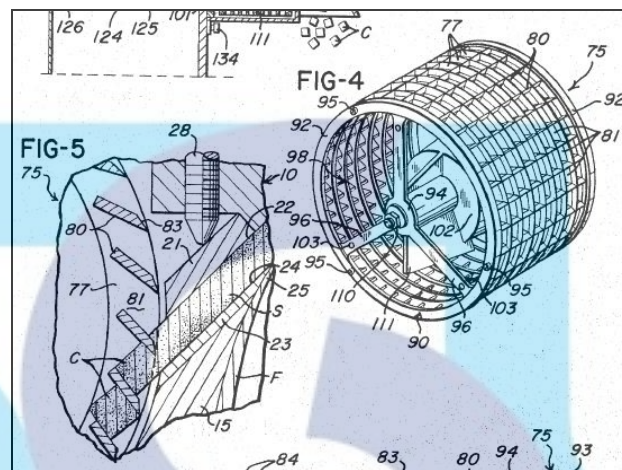


Figure 2.7 – Conventional dicer apparatus

Conventional dicer apparatus invention is intended to be able to slice or dice food articles into smaller pieces, without doing actions that may deform the pieces such as mashing or squeezing. Therefore, the original juice is retained within the cubes. The primary object of this invention is an apparatus that should also be able to process food articles under high capacity and continuous supply, most likely self-feeding. Self-feeding technique prevents food from being compressed or restricted. Another object is to avoid any deforming actions toward the food product and to provide easy and convenient apparatus to clean after the process is done. The focus on this invention relies on how to cut the food products but neglecting the aesthetical side of the product itself. (Tiby & Seine, 1968)

2.5.2 Dicer Machine with Improved Squareness

The visual appearance of the cut food product has been an important factor for customers in selecting a cutting machine. This involves the technology of food cutting into very specific features such as improved squareness of cubed pieces of a food product. The square cut is defined as one in which the sides of the cubed food product

are perpendicular to adjacent sides. The squareness plays an important part in the overall appearance.

Perfect square cut using the former conventional dicer machine is rather hard to achieve. The technology of the prior machine is a rotating circular shaped crosscut spindle and the knives can sequentially contact and cut the moving product what may have been cut into strips before. In the former machine, its position is not adjustable. Consequently, the cross-cut knife must process the food at exact proper speed and angle past the shear edge.

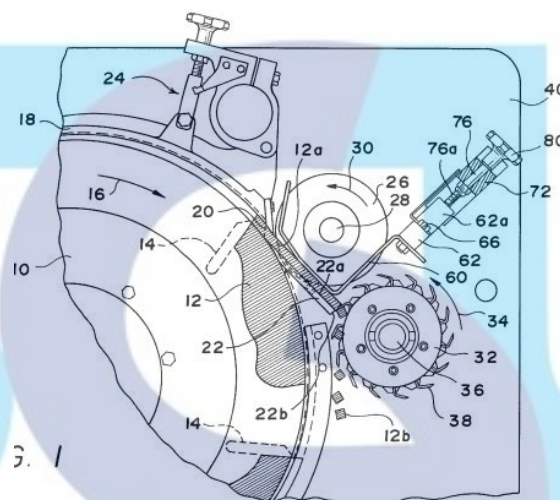


Figure 2.8 – The concept behind the improved machine

In Figure 2.8 – The concept behind the improved machine, stripper plates 60 is set to the stationary structure of the apparatus and are positioned for a specified thickness of sliced food product. For that reason, the food will be removed from the guide surface 22a, before a contact with the cross-cut knives. The location of the stripper plates is between adjacent pairs of circular cutting knives 26, to avoid the product drawn away from the guide surface. The stripper plate's position is adjustable for any thickness of sliced food product to ensure that the sliced food product follows the guide surface and not withdrawn by its tendency to adhere the circular cutting knives. Therefore, improved squareness can be achieved. (Arrasmith, 2001)