Converting Coconuts into Value-Added Products: Serving Christ by Serving the Poorest of the Poor

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Introduction

Jesus modeled the kind of ministry that he called us to emulate, ministering to both the spiritual and material needs of people (e.g., Mark 2:1-12). In Matthew 25, Jesus' parable of the talents is recorded, challenging each of us to consider the abilities and resources that God has entrusted to us as a stewardship. This parable is followed by Jesus' commendation to those who serve Him by providing food, water, clothing, shelter and medical care to the poor (Matt. 25:35-40). In a world in which more than 2.7 billion people live on less than $2/day[1], the opportunities to serve Jesus Christ by serving the poor have never been greater. Those of us in engineering and technology have been entrusted with especially significant opportunities to make a difference.

It is worth noting that the evangelical Christian community is giving a higher priority to ministry approaches that address the spiritual and material needs of people concurrently. For example, some missions groups are drilling wells and then building their church buildings next to the well, allowing the church to provide life giving spiritual and physical water (John 7:37-39). Rick Warren's Saddleback Church has adopted a church planting ministry strategy that uses the acrostic **P.E.A.C.E.**, **P**lanting churches, **E**vangelizing, **A**ssisting the poor, **C**aring for the sick, and **E**ducating everyone.[2]

In this paper, we seek to share one example of how engineers can minister as Christians by partnering with Christian organizations in developing countries to meet the basic needs of the people; namely, food shelter, clean water, housing, energy, and job opportunities. The Engineering and Computer Science School at Baylor University partners with Christian organizations in developing countries by designing and deploying appropriate technology that utilizes locally available, abundant, renewable resources in a sustainable way to improve the quality of life of the people. Coconuts are such a renewable resource in many developing countries around the world. In this paper we will share the research and development work that we are doing at Baylor to convert coconuts into electricity, housing materials, cooking fuel, feed for animals to make food for people, and jobs.

Coconuts: A Potential Blessing for Poor People Around the World

Coconuts are an abundant renewable resource in coastal regions within 20° of the equator. In Zone 1 coconut trees are highly productive, in Zone 2 they are moderately

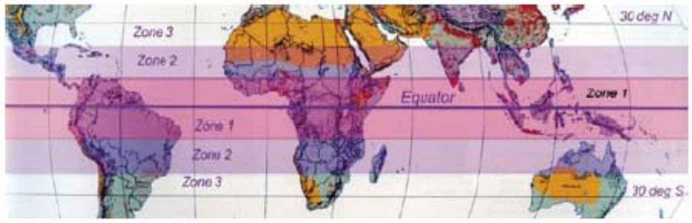

Figure 1. Coconut tree productivity around world[3]

Figure 2. Coconut trees with melons

productive, and in Zone 3 coconut trees grow but produce no fruit. Except for Singapore and Australia, countries in Zones 1 and 2 in Figure 1, while rich in coconuts, are poor and under developed. If coconuts could be converted into an ensemble of value-added products that could be utilized within rural villages or sold outside the village, the material well-being of the many people who live in regions where coconut trees are abundant could be greatly enhanced. Over 50 billion coconuts per year are produced by coconut trees, with 96% of these owned by very poor farmers with incomes of $1-$2/day. Our challenge is to take this abundant renewable resource that God has provided for the benefit of poor people in developing countries, and help them to understand how to utilize this wonderful, God given gift.

Constituents of Coconut Tree Melons – Coco Nucifera

Coconut trees produce 120 melon-sized fruits per year. Each fruit has approximately 1.6 kg of total mass, consisting of 35% husk, 28% copra, 12% shell, 5% milk, and 20% water in the husk, as seen in Figure 3.[4] Figure 4 shows just the shell and copra, or white inside of the coconut. The coconut can be purchased in grocery stores in the United States, but the husk has already been removed.

Figure 3. Constituents of Coconut Tree Melons

The copra in turn consists of about 50% water, 33% coconut oil, and 17% white meal. Next we will explore what value-added products might be produced from the copra, coconut shell, and husk.

Figure 4. Coconut shell and copra

Value-Added Products from Copra

Figure 5. Copra after removal from coconut

Figure 6. Coconut oil from copra

Figure 7. Tranesterification of coconut oil into coconut bio-diesel

Figure 8. Coconut bio-diesel + glycerin

The copra can be scraped from the coconut, as seen in Figure 5. Then the copra is dried to remove the water and the coconut oil is extracted by mechanical squeezing of the dried copra. Coconut oil is seen in Figure 6. The coconut oil has the best Iodine number and the best Cetane number of the 50 vegetable oils that have been studied.[5] The iodine number indicates how cleanly a vegetable oil will burn in a diesel engine, leaving few if any deposits in the engine. The Cetane number measure how easily various vegetable oils will spontaneously combust at higher temperatures and pressures.

The only problem with coconut oil is the viscosity, which is too high to be burned in a diesel engine if the fuel tank is at room temperature. If the coconut oil is to be used as a fuel in diesel generators for rural electrification, either the coconut oil must be modified to be able to run in a standard diesel engine or the diesel engine must be modified to burn pure coconut oil.

Using one part methanol to five parts coconut oil, with lye as a catalyst, the coconut oil can be converted by trans-esterification into coconut bio-diesel, with a viscosity similar to conventional diesel fuel, as seen in Figure 8. Trans-esterification is the process of exchanging the alkoxy group of an ester compound by another alcohol.[6] A byproduct of this chemical process is glycerin, which may be used to make soap.

We have run the coconut bio-diesel that we produced from pure coconut oil (see Figure 8). It runs extremely well with only 1/3rd of the emissions compared to petroleum based diesel fuel. The only potential problem is the necessity of using methanol in the transesterification process shown in Figure 7. Methanol is toxic, explosive, dangerous to transport, and not readily available in rural villages in developing countries. Therefore, modifying the diesel engine to burn pure coconut oils may be a more prudent approach. If the coconut oil is heated to 80C, the viscosity is similar to that of coconut oil, allowing it to be burned directly in a diesel engine.[7]

The white meal that remains after the coconut oil has been extracted contains 16% protein and may be used as feed for pigs and chickens, both of which eat it enthusiastically.

Value-Added Products from Coconut Shells

Like the coconut oil, the coconut shell also has exceptional properties. It has a specific gravity of 1.2, which is about twice the density of hardwood. It is at least twice as hard as hardwood and is also very rich in energy. The hardness of the coconut shell is comparable to lower strength aluminum alloys, making it one of the hardest organic materials produced in nature. It can be ground into 50-micron chips to potentially be used as reinforcement for engineering plastics. Chopped glass fibers are conventionally used as reinforcement to increase strength and stiffness and reduce cost in polymeric composites. Ground coconut shell is not as hard as glass, but it should bond much better to the matrix, since the bond interface will be organic to organic, rather than organic to silicon oxide. We are currently studying this option.

Because of its high mass-density, coconut shells also have a high energy-density. This means that they may be burned as fuel for cooking or used to make charcoal. Burning directly as a fuel would make more sense in the village, while sales to cities would be in the form of charcoal. While the burning of 10 kg of wood produces only 1 kg of charcoal, 10 kg of coconut shells produce 3.5 kg of charcoal and 5.5 kg of combustible gases.[8] We are exploring possible cook stove designs that would make efficient use of the energy from coconut shells, and we are also exploring how we might capture and store the combustible gases that are released as coconut shells are converted into charcoal.

Value-Added Products from Coconut Husks

The husk is 35% of the mass of the coconut melon. It is comprised of about 67% pith, a lignin which behaves like a phenolic resin[4], and 33% fiber, also made from lignin but with a fibrous morphology. The pith and the fiber can be used in agricultural applications since they absorb about ten times their weight in water. Furthermore, the pith and fiber are biodegradable, enriching the soil much like peat or mulch, for which they may be substituted. The husks (pith and fiber mixture) brings about \$0.18/kg in country for export in 10 kg blocks. The shipping costs from the Philippines to the United States of \$0.32/kg raises the price to about \$0.50/kg wholesale in the US.

Recent studies in the Netherlands[9] support the idea that the husk can be hot pressed into particle board directly without adding any additional binder. The pith can apparently chemically react and consolidate much like a phenolic resin, with the fibers serving as reinforcement.[4] Particle board in developing countries is usually in high demand and commands an excellent price. For example, an 8’x4’x0.5” sheet of particle board retails in Papua New Guinea for \$15, which is about two weeks’ wages for a villager[10]. The wholesale price for particle board is ≈\$10/board. This is equivalent to \$.70/kg, which is a much more favorable price than the previously mentioned agricultural use of the husk. The particle board can also be used in the village for housing.

Figure 8. Two examples of board pressed from coconut husks[9]

In current work we are exploring the processing window for hot pressing husks into particle board and determining the mechanical properties of the board formed. We are currently focusing on consolidating the pith by hot pressing before hot pressing the pith with fiber. A series of tests have been conducted in which we have hot pressed the pith (usually without fiber) at various temperatures and pressures, and then measured the Brinell hardness of the resultant particle board. It should be noted that we are making binder less particle board. It is worth noting that our manufactured particle board can be harder than hard wood, though this is probably unnecessary for most applications.

Two examples of binderless particle board hot pressed in our lab are seen in Figure 9. Note the high quality finish that is possible as well as the high hardness and strength. More recent tests on rectangular shaped pieces have indicated that we can make hot-pressed coco-board with twice the stiffness of particle board from Lowes and three times the strength. Ease of sawing, and penetration of nails without splitting, are under study. The best combination of temperature, pressure, density, and percentage of fiber — to give the best combination of mechanical properties and density, at the best price — remains to be determined.

Figure 9. Hot pressed particle board

We have recently learned that 80% of all particle board used in the United States is imported, and that more than 50% of the cost of this imported particle board is in the cost of the wood particles and glue used. Since our feed stock is very nearly free and requires no glue/binder, coco-board should be able to compete very well in the billion dollar global market for particle board.

Economic Assessment

It is interesting to speculate on what value-added one would one have from the products described above. Below is summarized what one might make from 100 coconuts, what these items might sell for wholesale, and what is the cost of the 100 coconuts and processing costs.

100 coconuts value **wholesale market price**

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- **2.5 sheets of particle board 4'x8'x0.5"….. $25**
- **19 kg of coconut shell……………………... $20**
- **8 kg of meal for animal feed……………… $ 2**
- **3 gallons of diesel fuel……………………. $18**

Total Income $65 / 100 coconuts

Or $0.65/coconut @ wholesale prices

- **Cost of coconut (>$0.06/coconut)…..…….. $ 6**
- **Cost to process coconuts (~0.08/coconut)... $ 8**

Total expense $14 / 100

Or $0.14/coconut

What would be the cost of the necessary processing equipment to convert coconuts into the value-added products at a village level?

- Capital costs
  - Coconut processing equipment (firm) $14K
  - Coconut shell grinding equipment (estimate) $25K
  - Hot pressing equipment/village $50K
    (estimated, assuming it is shared by
    10 villages for total cost of $500,000)

Total $89,000

The above equipment would be capable of at least the following production.

- 500 coconut/day x 300 day/yr x ($0.65-0.14) = $76,500 net income/year. (This figure could be increased if one used more than one 8 hour shift per day, with cost of $0.08/coconut as wages described above and coconut cost of $0.06)
- 1250 coconut trees required, which is easily met in most villages.

It appears that if the above economic analysis is accurate, then the capital equipment could be fully paid in 2 years.

Rural Electrification

The coconut processing described above would provide sufficient fuel to provide two light bulbs for 250 homes for 3 hours/day, with daytime electricity used for refrigeration of medicines, computers at schools, and commercial activities such as sewing. The cost of the electricity would be $0.45/kW-hr and would cost about $1.50/month per home (30 day/month x 3 hr/day x 2 bulbs/home x 20 watts/bulb x $.00045/w-hr) A 30 kW electric generator that is diesel powered will cost about $11,000. In rural villages that will likely never be on the grid, generation of electricity using coconut oil as a renewable and sustainable fuel source is extremely attractive. It will stimulate many other kinds of economic development and provide a much improved quality of life over the current situation where lighting is done with kerosene or propane lanterns, which provide low quality light, give off much smoke, and are relatively expensive to fuel. Importantly, the electricity can also be used to make sodium hypo-chlorate to purify drinking water using only water and salt as the starting ingredients.

Summary

Coconuts are a remarkable renewable resource that God has provided for the poor people in developing countries, with constituents that have many unique and superior properties. It seems feasible to take advantage of these unique properties by converting the constituent parts of the coconut melon into a variety of value-added products that can be consumed in the village or sold outside the village, providing food, housing materials, clean water, electric energy, and jobs in the village, all in a sustainable environment. It is our hope and prayer that God will guide us to good solutions as we seek to bring this promise to a useable reality that can be deployed worldwide.

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