# Science and Technology in Service of the Poor: The Case of the Coconut

*Walter L. Bradley*

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When I moved from Texas A&M University to Baylor University in 2002, my goal was to redirect my research activities from high-performance polymeric composite materials for the United States Air Force and NASA to something that would directly benefit the poor in developing countries. But what might this be? I started this journey of discovery by trying to determine the demographics of the poor in developing countries and learned that 80% of the 2.7 billion people who live on less than $2/day are poor farmers who have 2–5 acres of land.

Through John Pumwa, a former PhD student of mine at Texas A&M who was from Papua New Guinea, I learned that there were 11 million coconut farmer families around the world (see figure 1) who make $500/year selling the white coconut "meat" from the ~5,000 coconuts/year each family harvests for 10¢/coconut. These families live within ~20° of the equator where coconut trees grow and bear fruit (see figure 2).

**Figure 1.** Walter Bradley with a typical coconut farmer family.

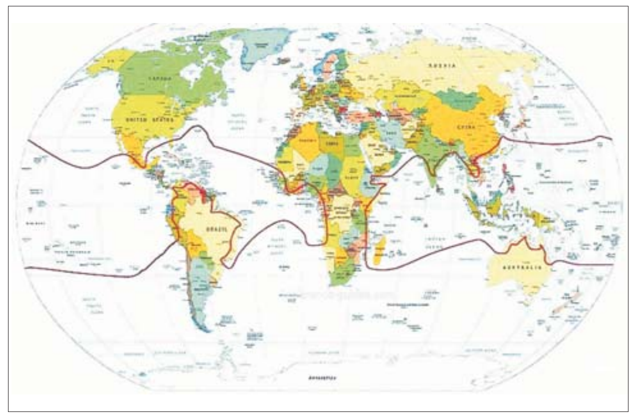

**Figure 2.** Regions inside the dark boundaries are locations where coconuts grow.

In this communication, I would like to share the details of my quest to make a difference in the lives of these farmers, both economically and spiritually.

## Coconut Biodiesel for Sustainable, Worldwide Rural Electrification—The Impossible Dream

Pumwa took a one-year sabbatical leave from his position as department head of mechanical engineering at the University of Technology in Papua New Guinea to come to work with me at Baylor University in 2004. Our initial goal was to determine if we could make biodiesel from coconut oil to provide electricity in rural villages around the world, such as the one where he was born in Papua New Guinea. Vegetable

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oils including coconut oil must be converted into long-chain hydrocarbons (10–15 carbon atoms in length) to be utilized as fuel in diesel engines. The normal process to make this happen is called transesterification, and is typically done using methanol in a mixture of one part methanol to five parts vegetable oil. We were able to demonstrate that coconut oil can be used to make a wonderful biodiesel fuel (see figure 3) that created sweet-smelling exhaust fumes and reduced engine friction.

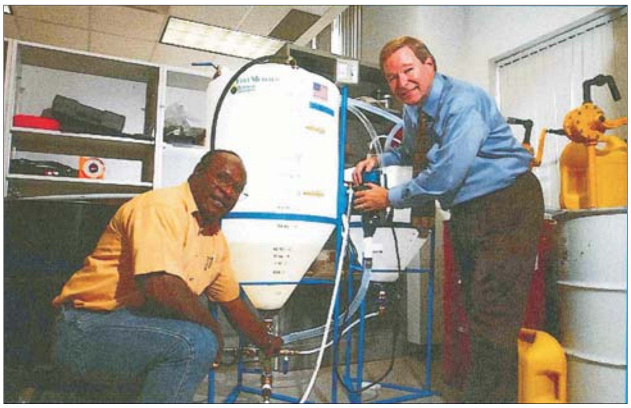

**Figure 3.** John Pumwa and Walter Bradley making their first batch of coconut oil biodiesel.

Unfortunately, methanol is not available in rural villages and rural villagers would not have money with which to purchase methanol, even if it were available.

Pumwa returned to Papua New Guinea while my research group at Baylor in 2005–2006 proceeded to explore a substitute for methanol in the transesterification step that villagers could make for themselves, namely, ethanol. With chemical stockroom-grade dry ethanol (essentially free of water), we made excellent biodiesel fuel from coconut oil. With 0.5 wt% water in the ethanol, we made acceptable biodiesel fuel from coconut oil. But with 1.0 wt% water in the ethanol, the transesterification process was poisoned, and we made soap instead. It is essentially impossible to make ethanol containing less than 1.0 wt% water in a rural village using a distillation still, so we had to abandon our "impossible dream" of providing sustainable rural electricity around the world. Any reader who is a chemist should ponder this challenging research project with its huge potential to benefit the poor in developing countries. How can biodiesel be made from vegetable oil using a chemical process that utilizes a chemical that villagers can create in a rural area?

## Plan B—Creating Biocomposite Materials from Coconut Shell and Coconut Husks: The Possible Dream

Next we turned our attention to the 50 billion kilograms of agricultural waste created each year in the production of coconut oil. What unique combinations of physical properties might biomass in coconut husks and shells have that would not only be useful but would also have a competitive advantage in providing market opportunities and value for this abundant but poorly utilized agricultural waste?

There are currently relatively few markets for the coconut shell and husk. Consequently, the shell and husk are often burned as fuel or as agricultural waste (see figure 4), providing little or no economic benefit to the farmers. The goal of my research since 2006 has been to create polymeric composite materials that utilize coconut fiber (called coir) and coconut shell powder as functional fillers in polymers such as polypropylene, giving significantly enhanced value to the 50 billion kilograms of agricultural waste that is owned by poor coconut farmers.

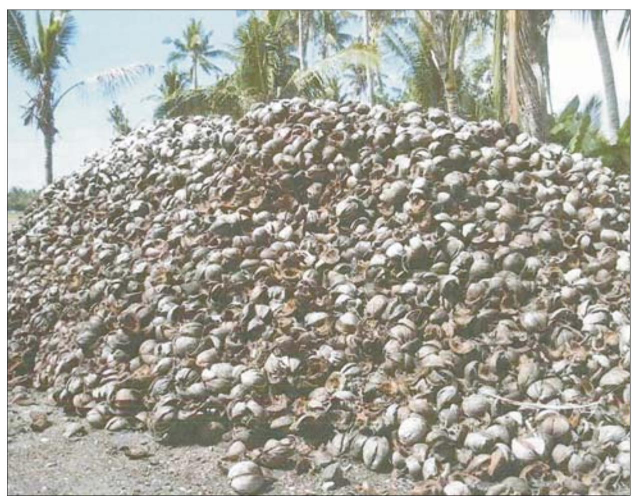

**Figure 4.** Coconut husk in the Philippines, an abundant agricultural waste worldwide.

A cross section of a coconut is seen in figure 5, with the primary constituents being the husk that surrounds the coconut, the shell of the coconut, and the white coconut meat, usually called copra. The coconut husk consists of 50 wt% fiber called "coir" and 50 wt% pith, which is a fine, powdery biomass.

*The Properties and Use of the Coconut Husk*

What are the physical properties of the various constituent parts of the coconut husk and what commercial opportunities do these properties provide?

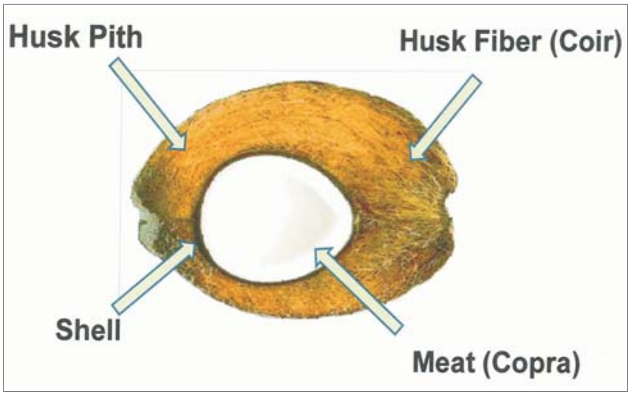


**Figure 5.** A cross section of a coconut husk and imbedded coconut shell.

The pith can absorb ten times its weight in water and is already widely used in horticultural applications. The function of the husk in nature is to absorb the impact energy from a 60–80-ft fall so that the seed, the coconut, is not broken. The husk must also protect the seed from fire and microbial attack. As a result, the coconut fiber has an unusually high elongation of 25–30% compared to most natural fibers with an elongation of only 1–3%. This gives excellent formability when it is used in nonwoven fabric composites.

The high lignin content of more than 35% makes the fiber resistant to microbial attack and difficult to burn. Natural fibers that are susceptible to microbial attack develop odor problems in service. The coir fiber has a remarkable structure (see figure 6) that gives it a very high stiffness-to-weight ratio, which reduces the cost per pound (it has a honeycomb-like core) and makes it particularly attractive for automotive applications. Finally, the coir fiber has a fiber diameter of ~200 μm, while most natural or synthetic fibers are ~50 μm in diameter. Flexural rigidity is proportional to the diameter.

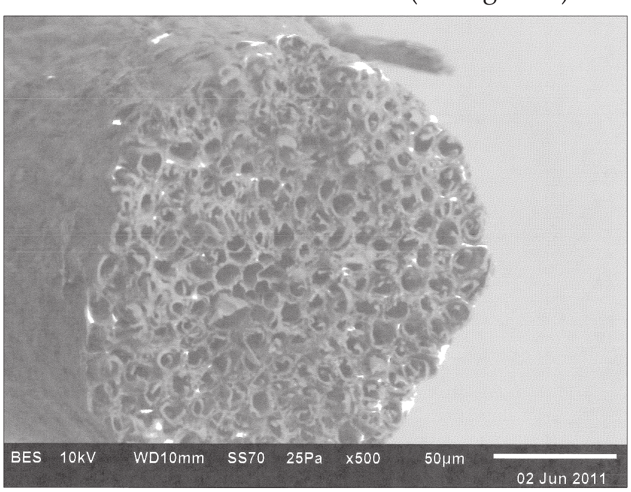


**Figure 6.** Cross section of a coconut fiber as seen in SEM showing a remarkable honeycomb-like structure.

Coir fiber can be blended with a synthetic "binder" fiber such as polypropylene or polyester and processed into a nonwoven fabric composite by carding and needle punching or by air-laid processing. The fabric composite can then be processed into parts such as door panels for automobiles, as seen in figure 7, or mattresses for beds, cushions for furniture, or many other applications.

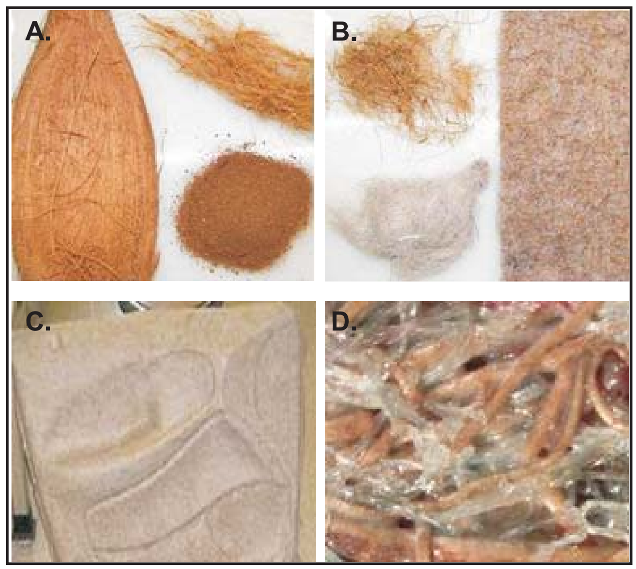


**Figure 7. A.** Coconut husk contains fiber and pith; **B.** Coconut fiber is blended with polypropylene fiber to make a felt; **C.** Automobile door panel made by heating felt and compression molding it; **D.** Felt after compression molding.

The high fiber elongation of coir, as compared to other natural fibers, provides excellent formability for production of parts by compression molding of nonwoven fabric composites that utilize coir, as seen in figure 8.

One part in the 2012 Ford Focus is manufactured using coir fiber in a nonwoven fabric composite. Ford Motors nominated this part of an automotive innovation award from the Society of Plastics Engineers in 2011, and it was selected as the first runner-up in its category of sustainable materials. Several major nonautomotive applications are at various stages of development in collaboration with major companies.

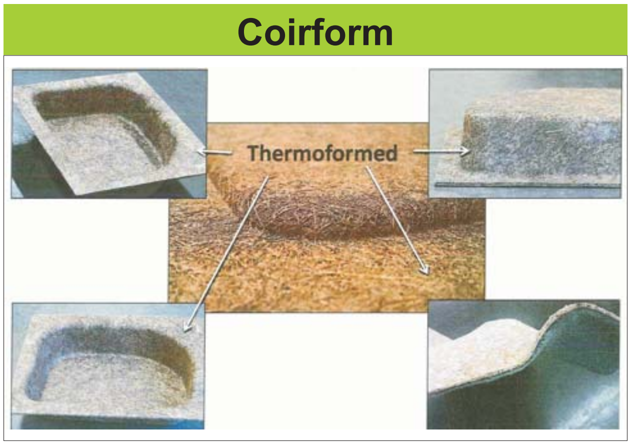


**Figure 8.** Excellent formability in compression molding of nonwoven fabric composites with 50 wt% coir.

The coir research and development work was made possible by two grants from the National Collegiate Inventors and Innovators Alliance (NCIIA) totaling $40,000 and subsequently by three National Science Foundation Small Business Innovation Research Grants totaling $1.1 million.

### *The Properties and Use of the Coconut Shell*

What are the physical properties of the various constituent parts of the coconut shell and what commercial opportunities do these properties provide?

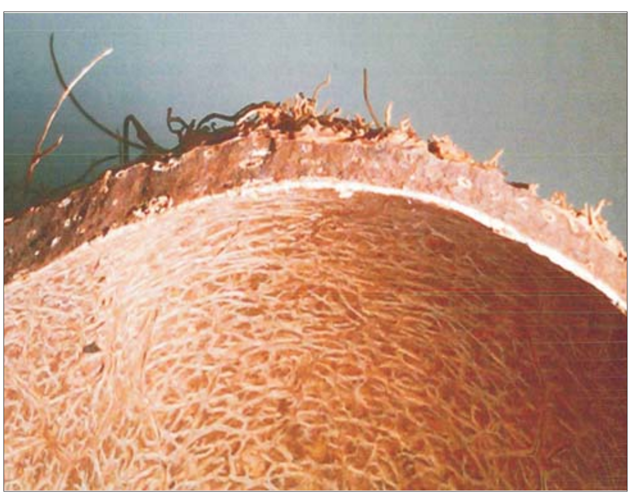

**Figure 9.** Coconut shell.

Coconut shell is extremely dense (1.2 g/cm$^3$ compared to most wood at 0.3–0.6 g/cm$^3$), which makes it very hard (four times harder than maple and ten times harder than pine). Its high lignin content makes it resistant to attack by microbes including mold, and also more difficult to burn.

The coconut shell can be processed into coconut shell powder (CSP) (see figure 10) and utilized as functional filler in plastics such as polypropylene to increase their hardness and stiffness. The coconut shell powder is eight times as hard as polypropylene and can easily double the stiffness of polypropylene when added at the level of 40 wt% as functional filler. It can be used in applications in which consumer goods are manufactured using injection molding, extrusion, or thermal forming (see figure 11).

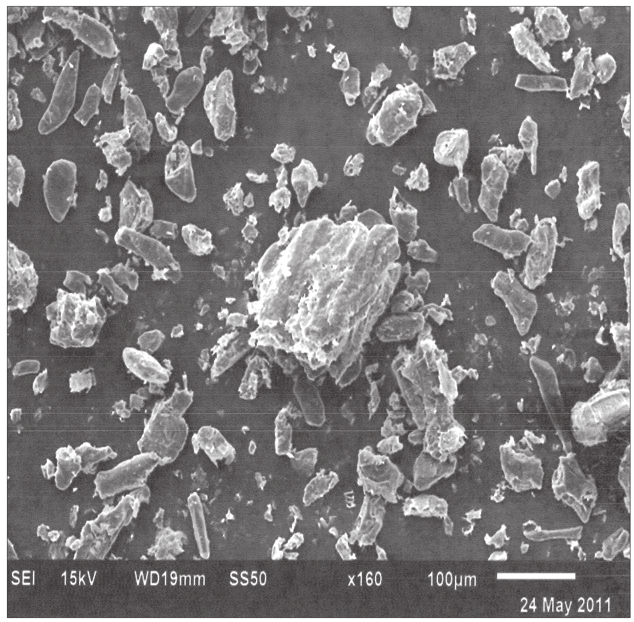


**Figure 10.** Coconut shell powder as seen in a scanning electron microscope.


**Figure 11.** Examples of consumer goods that can be made from coconut shell powder (CSP).

Joint development projects with major manufacturing companies are already underway, with multiple products to be introduced in 2013 that utilize coconut shell powder as a functional filler in polypropylene.

### *Benefits to the Poor in Developing Countries*

Production facilities have been purchased in Indonesia by Natural Composites Inc., the company that I founded in partnership with Christian friends who share my vision of helping poor people in developing countries in a for-profit company. This facility is capable of producing 10 million pounds of coconut shell powder per year and provides employment for ~100 people working in the plant. The employees are treated extremely well and are thankful to have a job to support their families. The number of employees should grow significantly over time as the use of coconut shell powder as a functional filler in polypropylene, and coir as a constituent in nonwoven fabric composites, expands. We also anticipate creating other production facilities in the Philippines, India, Sri Lanka, Brazil, and maybe in a country in the Caribbean.

We also plan to develop cooperatives with the coconut farmers so that we can buy coconut husks and shells from them directly. Currently, we buy from middlemen. Direct buying will allow us to provide more benefits to the coconut farmers and to build relationships with them. Rather than paying a premium for what is currently a very cheap commodity (even free in some cases), we will seek creative ways to benefit the farmers and their families, such as by providing vouchers for their children to go to nearby schools that would be created by concerned Christian businessmen and churches, or by providing fertilizer to help them double the yields of their coconut trees.

Concerning our employees and our coconut farmer suppliers, we plan to bless them by dealing with them in a Christ-like manner and, over time, by taking the opportunity to share the love of Christ with them.

## Personal Postscript

When I moved from Texas A&M University to Baylor University in 2002, my goal was to redirect my research toward something that would directly help poor people in developing countries. I had no idea what that might be. God has led me on an amazing faith-stretching journey for which the past thirty years of my life were a preparation. The skills I developed and the friends I made prior to coming to Baylor have become the technical tools I needed and the partnerships I must have to be successful in this venture. It is very clear to me that "unless the Lord builds the house, those who build it labor in vain" (Ps. 127:1a).

When I was asked by ABC News in 2009 how I ever thought to use coconut husks to make automobile interior parts, they assumed that I would explain how I tirelessly tried every natural fiber and determined, by a process of elimination, that coir was the best. But God directed me to coir as he brought to my attention, through John Pumwa, the plight of the poor coconut farmers. Happily, their agricultural waste was pregnant with possibilities. The amazing band of brothers and sisters who have become part of this journey include former members of a young married couples Sunday School class that I taught twenty years ago, friends from a Christian businessmen's annual ski conference in Colorado over a period of ten years, and a whole host of students whom God brought to my classes, especially John Pumwa, the first student from Papua New Guinea to earn a PhD in engineering and whose parents were the first in his mountain village to accept Christ as their Savior many years ago.

Oddly enough, I was diagnosed with leukemia about the time I started this journey, with a life expectancy of three years. Here I am seven years later, living on "borrowed" time, doing perhaps the most important work of my life. When I was first diagnosed with leukemia, I prayed to God for fifteen more years, just as Hezekiah did, with the promise that I would try to be a better steward than he was with such a gift. This work is my down payment on that promise. Hopefully, God will grant me the privilege of seeing it come to full bloom. ✠