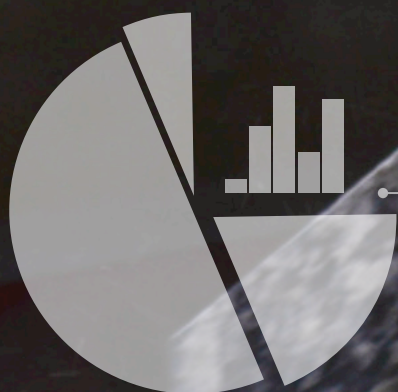


SECTOR STUDY PROCESSED MANGO



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This document is part of the mango sector study. This study explores the technical and economic feasibility of different processing and waste valorisation activities. The other chapters are available here: [resources.colead](https://resources.colead.org/)

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1. What are mango briquettes ?

Briquettes are made from mango waste. They are an alternative source of fuel to electricity, gas or even wood. They are used as fuel in homes for household stoves. In industry, briquettes are used as fuel for boilers. These briquettes can be made from a variety of agricultural waste, which is made denser and then dried, after which they are ready for burning.

Mango briquettes are a new option. These briquettes – in the few instances when mango briquettes have been made – use the inner kernel of the mango pip as the core ingredient. The mango kernel is crushed and dried, before adding a binding agent. It is then pressed into shape.



2. Demand

Energy is a major challenge in much of the developing world. In Africa, access to electricity remains a privilege: 645 million Africans have no access to electricity. In most of the Southern African Development Community (SADC), roughly a third of the population does not have electricity.

Electricity supplies can also be unstable. Power outages are regular occurrences in many countries. It is no surprise then that electrification, sustainable energy, LPG (liquefied petroleum gas) and other fuel source projects are on the agenda of many governments and development agencies across the continent. These projects face significant challenges. Shortages of funding and even electricity poles in many countries place the ability to expand the power grid fast enough to meet demand into doubt.

Households and industry are thus challenged to find their own solutions to their energy crisis – at least in the short term.

2.1.1 Household use

Firewood is still the dominant fuel used in rural areas. It is usually gathered by women and children, and therefore perceived as being free. Any product that needs to be purchased will struggle to compete with firewood, despite its many disadvantages. These disadvantages are mostly the time lost in finding wood and transporting it home, the time needed to prepare a fire, the smoke and dirt. However, none of these things primarily impact men who are often the main decision makers in rural households.

Poorer peri-urban and urban consumers tend to use charcoal, which needs to be bought. This is the primary space where mango briquettes can compete – if they are cheaper, burn better and longer than charcoal, or are easier to use.

More well-off urban consumers tend to cook on gas or in some cases electricity, and converting those back to open fires will be difficult. Gas is much easier to use. However, if briquettes would be much cheaper, they could perhaps substitute a small part of gas. The current record high gas prices would potentially help.

Over the past decade there has been a large shift in many countries from firewood and charcoal to gas. This is because charcoal is becoming more expensive as wood becomes scarcer due to deforestation. Charcoal makers need to travel further which increases cost. Gas is also increasingly subsidised and promoted to convert people away from charcoal. For example, in Ghana the market share of gas increased from 2% in 1995 to 25% in 2020.

2.1.2 Street vendors

Another market for briquettes would be street vendors, who normally prefer softwood charcoal that is easy to fire up for quick food preparation.

2.1.3 Industrial application

Finally, there is an industrial market. Many food processing plants require hot water, steam or heated air. This is generated in industrial boilers. In this market, mango waste would compete with cashew shells, coconut husk, firewood, sugar cane waste, rice husk and other biomass. For this market, flames, odours and ease of burning are less important, because the fuel is added to a continuously burning large fire inside a fire box. Pressing mango waste into briquette shape is not necessary either. Calorific value and cost are the most important factors, along with residues after burning. However, price is a major barrier, as most biomass currently used can be obtained for free. The costs are also limited by transport cost. Most rice mills and cashew plants do not know what to do with their waste.

2.2 Relative pricing

Briquettes are a direct substitute for charcoal. Thus, to gain market share the product needs to offer the same performance at a lower price, or better performance at the same price. However, in vast parts of Africa, charcoal prices are so low that it may be difficult to compete. The cost of producing one tonne of briquettes in Africa is up to US\$21, while for wood fuel it is around US\$9. For instance, in South Africa, a 4 kg bag of firewood retails at about US\$1.5 and 0.25 kg of coconut shell charcoal for US\$3.5.

Briquettes need to be sold at similar prices to charcoal. Because charcoal is heavy and bulky, and has a low value by weight or volume, transport costs are a big cost component. There also tend to be many intermediaries involved. A producer may sell directly at the roadside, or to a trader who will take it to an urban area. Traders sell to retailers who sell to consumers. As a result of this chain, charcoal prices in cities are often double those in rural areas.

Price comparisons between countries are difficult because charcoal tends to be sold by volume (bag) rather than weight. The size of the bags can be different. Furthermore, the weight depends on the type of wood used and the degree of burning/carbonisation.

To provide some indication, the average charcoal price in Ghana was GHS1.2 (€0.14) per kg in 2020 – from GHS0.8 in Tamale to GHS1.6 in Accra. Current (2022) Burkina Faso rural mango area prices are €0.10 per kg, and prices in the capital may be double this. However, the sale price for a producer may be as low as €0.05 per kg.

In South Africa, charcoal and briquettes are much more expensive and are sold by weight, at roughly €0.70 per kg. In most value chains, retailers, wholesalers, and transport and logistics account for two thirds of the retail price. A producer will likely get about a third of the sales price. After retail and wholesale margins and transport costs are deducted, we can assume that the factory gate sales price for briquettes in South Africa is about €0.23 per kg. The difference in price is most likely the result of the fact that charcoal and briquettes are more often produced by formal companies who obtain wood in a legal way and must pay for it.

Based on the above, it seems obvious that competing with charcoal made from illegally harvested wood will be a challenge. Should government controls on illegally harvested wood for charcoal be better implemented, or if the wood supplies continue to decrease, we can expect that charcoal prices will increase. This could create more of an opportunity for mango briquettes, but that is not the case today.

2.3 Buying criteria

Most households and even companies use a basket of energy sources at any one time. This could be firewood, briquettes, hardwood charcoal, softwood charcoal or even gas and electricity. They then carefully select what they will use on each occasion, for their budget or even the availability of the energy source throughout the week or year.

Firewood, briquettes and other materials that allow for cooking and heating by open fire are all similar. As a result buyers have similar buying criteria when assessing the quality and benefits of briquettes. Most buyers first look for a material that is combustible. That means that it might burn easily, gives off a great deal of heat, can burn for a long time and creates very little smoke or bad smells. They also consider whether the material is easy or challenging to handle, transport and store.

2.3.1 Combustibility

The issue of combustibility is not as straightforward as it seems. Few materials have all of the qualities mentioned above. So, buyers need to make trade-offs when choosing what type of open fire fuel source to buy. This is also true when choosing the type of briquette, or even which supplier of briquettes to source from.

This is largely because the characteristics of combustibility that buyers prioritise change for different contexts. For example, Ghanaian street-food vendors might have a preference for soft wood charcoal that is easy to light and quick to reach temperature. They need to fire-up quickly if a client comes and they have no assistant on hand to tend to the fire while it gets to temperature. In households, this need for a fast fuel source is not as important. The fire can be lit early. In some homes children are given the responsibility of tending to the fire. A slower-burning hardwood charcoal, a dense briquette, or even firewood serves their needs just as well.

Even households might have very different preferences from day to day depending on what they are cooking. If someone is preparing a chicken, and they bought softwood charcoal for cooking they could be disappointed. It heats up quickly, but the heat is not long lasting. On this occasion they could choose harder briquettes or hardwood charcoal, which gives off heat that lasts for the 40 minutes to an hour needed to thoroughly cook the chicken.

These varying preferences make things challenging for mango briquette manufacturers. There are many options and no clear answers when it comes to how combustible a mango briquette should be. There is also not enough market experience to assess what people are willing to accept in terms of market price. The end use of the briquette and what their customers purchase matters. It is thus important that companies producing mango briquettes get a clear idea of the dominant uses of firewood, charcoal and briquettes. They should then decide on whether they should produce a dense, longer-burning briquette, a softer, more combustible one, or even a range of briquettes to cater for various customers and end uses. Further research and ideally a test market is needed to really give firm answers to this question.

2.3.2 Handling, logistics and storage

A quality briquette should be easy to handle. It should be hard enough (dense) so that it remains intact during transport and storage. This is called having low friability. The material also should not absorb lots of moisture from the air and should be at least partially resistant to light rain or small water spills. But, even here there are trade-offs that need to be made. If the briquette is too compact and too hard, it is not easily combustible. As a result it will not catch alight easily. But, if it is too soft it will break apart in handling.

The challenge in manufacturing briquettes is finding the sweet spot where the briquette is firm enough to withstand the rigours of manufacture, packing and transportation, but still loose enough to allow for good combustion. The sweet spot is not really clear. It is also affected by the degree of handling, transport, stacking and storage that is needed. Local sales in small bundles might allow for a softer, more friable briquette. But, if the briquette needs to be loaded onto a truck and transported to distant urban centres, the recipe will need to allow for a tougher, more resistant briquette.

This is very market dependant. Commercial mango briquette manufacturing is still relatively new and untested – especially at large scale. So, it is nearly impossible to paint a picture of exactly what recipe will create specific characteristics. This and what buyers will be willing to pay would need to be tested in the marketplace.

2.4 Market trends

2.4.1 Energy poverty



Many governments have been investing in expanding access to LPG, gas and electricity. In some countries, progress has been rapid (e.g. Tanzania). Nevertheless, for many less affluent households these sources of energy are not available, or are still too expensive to use all the time. Open fires then play an important role in keeping families warm, their homes lit and cooking their food. Even electrified homes, or those with access to LPG, might switch between different fuel sources, depending on the cost-effectiveness and convenience of doing so. Foods with shorter cooking times (e.g. frying eggs) might make gas sensible. Longer preparation times for meals such as beans might make firewood or briquettes more economical.¹

2.4.2 Blended energy sources

Households and businesses in Africa tend to use a blend of energy sources, as electricity and other fuels are often too unreliable or expensive. In some countries, cheaper fuels such as firewood and briquettes are needed to fit in with lean budgets for energy. This is especially true in times of economic crisis, making the case for briquettes especially strong since the start of the COVID-19 pandemic and now during the Russia–Ukraine conflict.



¹ Netshipise, L.F. and Semanya, K. (2022) 'Evaluating factors influencing firewood consumption in households at the Thulamela Local Municipality, South Africa'. *Journal of Energy in Southern Africa*, 33(2): 48–62. <https://dx.doi.org/10.17159/2413-3051/2022/v33i2a9741>

2.4.3 Deforestation

Increasing deforestation is making access to firewood more challenging for many rural households. Firewood, the most affordable household fuel, has several disadvantages. First, for those collecting it firewood is often difficult to find. Deforestation is a major challenge in most parts of Africa. Ghana, for example, is estimated to have the highest rate of deforestation globally. This forces mostly women to forage further and further away from home to find new sources of firewood.



2.4.4 Urbanisation



Urban residents have less access to firewood. Those looking for cheaper fuels can turn to briquettes. The trend towards urbanisation is still strong over most of the continent, which suggest that demand for affordable fuels such as briquettes is likely to increase.

2.4.5 Street vendors

Street vendors, many of whom sell grilled meats, fish or chicken, need briquettes for their businesses. Demand for meat is growing in most countries in Africa, which creates many opportunities for street vendors who sell foods. With growing urban populations, and an emerging middle class in some urban centres, there are opportunities for companies that are able to supply relatively clean, low-smoke, low-odour, cheap briquettes.



3. Supply

3.1 How do these products reach the market, what is the structure of the value chain?

Because it is so different from the business model of processed mango processors, and comes at a time in the year when they are most busy, briquette production is likely an activity best left to a separate investor. We can then assume that the briquette company would collect waste from factories, process it into briquettes and then sell the briquettes to wholesalers. These wholesalers or distributors would in turn sell to retailers, for example neighbourhood shops, market vendors or street vendors. This is a common structure for fuels and so we can expect that this would be a sensible approach for mango-waste briquettes.

It might also be possible for the processor to produce briquettes for a specific industrial buyer.

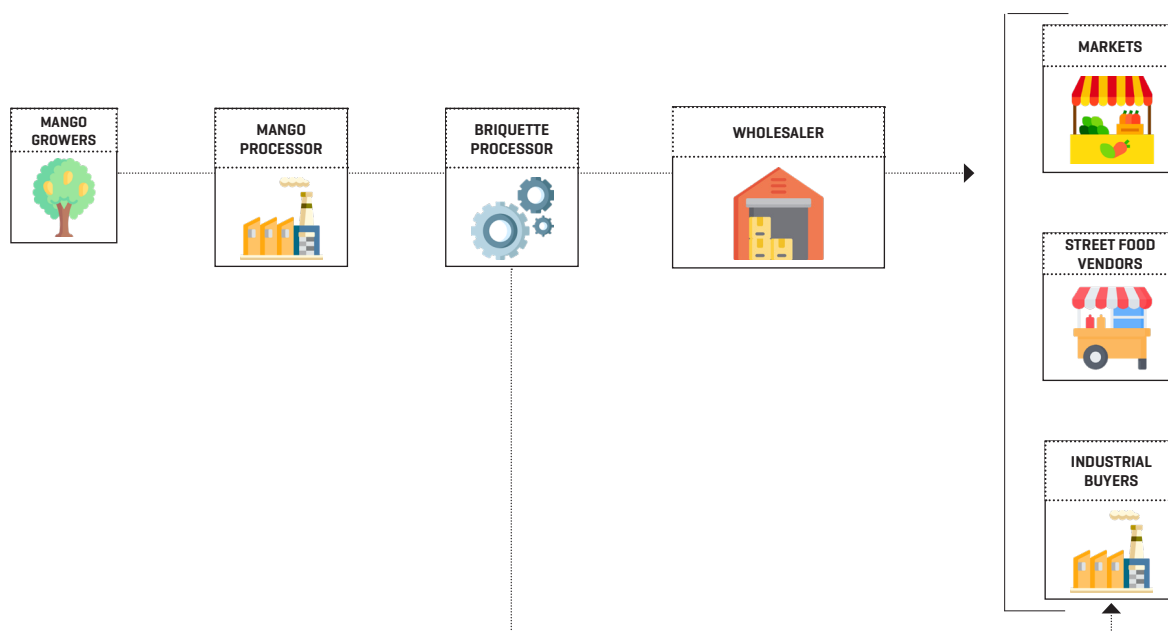


Figure 1. Overview of the briquette value chain

3.2 Seasonality

Mango-waste briquettes might not suffer from seasonality themselves: once well packaged and stored in a suitable place they can last for more than six months. Nevertheless, mango-waste briquettes rely on the mango season.

There are generally two mango seasons – a minor one and a major one. Mango processing happens during these seasons, making waste available then too. Outside of these harvest seasons, little waste is available, except from processors who source mangoes regionally, which have waste available for longer periods of the year.

Table 1 shows the major and minor seasons in a few African countries, i.e. when waste from local production is available. It is important to note that the length of the season might not reflect the volume of waste available; this is determined by the scale of production and the degree to which the ripe fruit is processed.

Table 1. Calendar of the mango season in various producing nations

	J	F	M	A	M	J	J	A	S	O	N	D
Senegal												
Burkina Faso												
Mali												
Côte d'Ivoire												
Ghana												
South Africa												
Kenya												

	Major season
	Minor season

3.3 Technology, processes and techniques

Briquettes are normally made with three ingredients – the main fuel source, a binding agent to hold the briquette together and a chemical additive that is sometimes added to enable the briquette to catch alight faster. Some examples of these ingredients are listed in Table 2.

Table 2. Example ingredients used in briquette production

Main fuel source	Binding agent	Chemical additives
<ul style="list-style-type: none"> Coconut husk Mango peel Biochar Cashew nut shell Rice husk 	<p>Optimal binders:</p> <ul style="list-style-type: none"> Cassava starch Rice starch Maize starch <p>Suboptimal binders</p> <ul style="list-style-type: none"> Acacia gum Molasses Cement Clay Tar 	<p>Ignition agent:</p> <ul style="list-style-type: none"> Sodium nitrate Sawdust <p>Ash whitening agent</p> <ul style="list-style-type: none"> Borax Sodium nitrate

3.3.1 Binders

Materials with high lignin content are the most recommended as binders, because lignin is insoluble in water, is stable and can act as “glue” for the various ingredients in the briquette recipe. Lignin is also combustible.

Wood, potato, maize and wheat starch and flour are all rich in lignin, even if the vegetable sources tend to be less so. Some other binders can be considered, including clay, gum arabic and molasses.

The binder needs to be carefully selected as it can also be a source of smoke, unpleasant odour, and poor ignition and burning. In some settings this might not be tolerated by the buyer.

3.3.2 Production process



Figure 2. Typical biomass briquette processing stages

Stage 1: Reception of raw materials

In this step, mango waste is received at the factory. It is then sorted, and the pips are separated from the waste. The pips will become the base raw material for the briquettes. It is possible to blend other agricultural waste, or even biochar into the briquettes. In this case these raw materials are also received. Some raw materials need to be carbonised first – these are burnt to create a biochar. This is then ready for use in the final briquette recipe.²

Stage 2: Pip shell and kernel separation

To produce quality mango-waste briquettes, it is important to manage the water content in the product. The pip shell is thus removed from the kernel. Typically, this is done manually. This allows processors to remove the kernel, which can be used for oil production. The shell then needs to be dried. This can be done in the sun or using a drier – at least in theory. The mango harvest in much of Africa is in the wet season making sun-drying a challenging route for most companies. It also requires a lot of space and time.

Stage 3: Shredding and binding

In this stage, the mango raw material is shredded and the materials are mixed. The finer material is easier to bind. Water and a binder can be added at this point. For mango briquettes, binders may not be necessary due to the lignin in the pip shell. However, more testing is needed to determine whether the product can then withstand transportation and handling from the factory to the end market. This differs for each company and their customers. Binding may also be required when adding additional ingredients such as cashew or rice paddy husk.

Stage 4: Compacting

In this step, the raw material is ideally formed using a hot press method. The raw material is fed into a briquette biomass machine, which binds the materials further and forms the briquette. Cashew briquettes, which are better known, tend to be about 5.5 cm in diameter and 10 cm long. This would be a good benchmark for the size and shape of mango-waste briquettes.

Some trials have tested cold compression. This uses a screw press and pressure to form the briquette. However, this might not be suited to mango-waste briquettes, especially if no binder is used in the formulation.

Stage 5: Drying of briquettes

The briquettes are then left in the sun to dry. Some companies might use specialist drying machines, but this then increases the cost of the briquettes.

² Sawadogo, M., Tchini, S., Tanoh, S. et al. (2018) 'Cleaner production in Burkina Faso: case study of fuel briquettes made from cashew industry waste'. *Journal of Cleaner Production*, 195: 1047–1056. <https://doi.org/10.1016/j.jclepro.2018.05.261>

3.4 Equipment

Producing mango briquettes requires a lot of equipment:

- Mango pip shell cutter, to split open the pip and remove the inner kernel
- Chipper to grind the mango pips and blend with other ingredients
- A blender may be needed
- Briquette biomass machines to heat the pulp and press it into briquettes.

Economic viability

Looking at what needs to be done to produce briquettes with mango waste, it is obvious why there is currently no commercial-scale production – it is too complex and expensive. Plus the yields and thus volumes will be too low. So, there is a real question of whether drying of pips and the final briquette is possible in the harvest season.

First, the only part of the mango that can be used is the pip, and this is difficult to separate from the rest of the mango. Mango juice factories put skins and pips together. Drying factories can separate pips from peels, but are not always interested in this added complexity. Furthermore, the pips will still contain some mango flesh, which may affect the product and may need to be removed. Finally, rotten mangoes that are largely intact are also an important waste stream that can probably not be used for briquettes unless a machine is added to take out the pip. For all this, either a lot of manual labour is needed or machines need to be developed and purchased, which will add to the production cost.

The second issue is that the pip has an outer shell and an inner kernel. The shell is hard, fibrous and contains lignin. The inner kernel, however, contains a lot of water and is difficult to use. The complete mango kernel still has 44% moisture content. There are two strategies here.

1. The whole pip is shredded and then may need to be dried before briquetting.
2. The outer shell is separated with special machinery, and then shredded.

The first option will increase the water content, which may lead to a longer drying time after pressing, or may require drying even before pressing. On the other hand, some water is needed in the compacting process, so it may not make a difference. The oil content of the inner pip may also lead to additional smoke and smells.

The third issue is the low yield. Depending on the variety and the size of the fruit, about 50–60% of the fruit is flesh and 20–25% of the weight is pip, while the rest are peels. This pip has about 45% water. This means that a completely dried pip is only 12% of the weight of a mango. If only the outer layer of the pip is used, this may halve. So one tonne of mango will only yield about 60–120 kg of briquette. A mango typically weighs about 600–700 grams, which means that 1,538 mangoes make a tonne. Thus, about 1,500 mangoes would be needed to produce around 100 kg of briquettes. This is a lot of work to produce a small amount of briquettes.

The fourth issue is the drying that is necessary after production. Mechanical drying will almost certainly make the product too expensive. Sun drying on the other hand is difficult because a large part of the mango season coincides with the rainy season. Furthermore, it would require a lot of land and labour to spread out the briquettes for drying.

In conclusion, to be able to produce 100 kg of briquettes a company would need to:

1. separate pips from peels and mango flesh for 1,500 mangoes
2. potentially remove fruit residues from the pips
3. possibly remove the inner kernel, shred the pip
4. potentially purchase and add a binder and blend this in
5. spend energy on heating and pressing the briquettes
6. dry the product during the rainy season
7. collect the briquettes, weigh and bag them.

After all this, we would get about 100 kg of briquettes, which typically would sell for about €0.10 per kg. The total revenue would then be €10 for a wage of 1,500 CFA (€2.30). Even with the low wages in Africa this revenue only allows for wages for two people for a day. We must ask whether this activity is viable at all.

4. Ingredients for success

4.1 Not economically viable

Briquette production from mango pips is not likely to be economically feasible anywhere (see Box), but certainly not in most of Africa where charcoal made of illegally harvested wood is available and cheap. The amount of work needed to produce briquettes from pips simply makes the product too expensive.

The only chance for success is in formal economies where charcoal prices are high, but these do not tend to be mango producing countries. However, those countries tend to have an abundance of waste from processing that would be far easier to transform into briquettes than mango pips.

4.2 Issues and opportunities summary

Table 5. Issues and opportunities

Opportunities	Issues
<ul style="list-style-type: none">▪ Demand for cheap energy from households and industry.▪ Open fires remain an important part of the energy mix for households and street food vendors.▪ Availability of raw materials, some of which are free or very low cost.▪ Space for different types of mango briquettes – soft, hard, long burning and easy to fire up.	<ul style="list-style-type: none">▪ The process is not simple and it requires a company to make many choices about the recipe based on relatively little available market information.▪ Mango briquette production is largely untested commercially, which raises many challenges for a company.▪ The complexity means that mango processing companies are unlikely to themselves take up this activity, especially as it requires production in the mango processing season.▪ Companies will need to invest in technology despite low revenues.▪ This is a challenging business model on all levels, including whether it is financially sensible to invest.

SECTOR STUDY: PROCESSED MANGO

1. Fresh cut mango
2. Dried mango
3. Mango puree
4. IQF mango
5. Mango pickle
6. Mango vinegar
7. Mango butter
8. **Mango briquettes**
9. Mango based compost



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