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SYNTHESIS OF THE THEMATIC DISCUSSION ON

OIL AND WATER

INTRODUCTION

There are many products derived from Moringa seeds. These include seeds itself, for propagation purposes, oil and presscakes, flocculent extracts, and filter cakes, which result from the presscake following water extraction of flocculent active agents.
We grossly analysed the production costs of oil and its sub-products, their potential utilisation and the associated target market.

OIL PRODUCTION

The technology of oil production includes seed production, their transport and storage (on a short-term basis), dehusking (a facultative step), packaging, and finally pressing and cleaning (through sedimentation or filter press).

Obviously, in this process, the main cost is linked to seed production. It has been estimated that the cost of seed production for two-year old Moringa trees (average yield=1,000 kg/ha) is around 0.3 $/kg. This production cost is expected to be lowered to 0.15 to 0.08 $/kg for mature trees (from 4-year old), assuming an average yield of 3,000 kg/ha.
A limiting factor of Moringa oil production is clearly related to the pressing step. Indeed, extraction yields of 20 to 55% have been obtained in different conditions, depending on the type of press used (manual, Sundhara or hydraulic). This is to be compared to the extraction yield of 85% commonly obtained with usual oily seeds like sunflower or rapeseed.
Table 1 gives an estimate of the net cost of Moringa oil, as well as of the capital of investment and the rate of oil production, potentially obtained with various extraction systems: small scale (manual press), semi-industrial scale (small motorised press) and industrial scale (large motorised press). The net production cost is calculated assuming a cake value of 0.15 $/kg as cattle feed.

Table 1: Moringa oil production cost, investment and rate of oil production using various extraction systems

	MANUAL *	SMALL MOTORISED *	LARGE MOTORISED
Efficiency	25%	50%	54% (?)
Oil extraction by weight	6.6%	14%	16%
Ratio oil/seed	1:15	1:7	1:6
Capital operation cost/kg oil	$ 1	$ 0.76	$ 0.40(?)
Seed cost/kg oil	$ 5	$ 2.21	$ 1.98
Total cost/kg oil	**$ 6**	**$ 2.97**	**$ 2.38**
Cake/kg oil	14 kg	6 kg	5 kg
Cake Value (0.15 $/kg) @	$ 2.10	$ 0.90	$ 0.75
Net cost of oil/kg	**$ 3.90**	**$ 2.07**	**$ 1.53**
Highest temperature (°C) during pressing	60°C	110°C	(?)
Investment	$ 170	$ 4,700	(?)
Kg oil/hour	0.5 kg/h	4.5 kg/h	-

* Data from MAFE project Malawi

@ excludes Phytofloc^{tm} extraction

Note that these values are only estimations, based on the average yield of the trees for a mature plantation. Currently, the only data available, based on experience, of Moringa oil production costs are those of the MAFE project in Malawi (semi-industrial scale) and of Optima of Africa Ltd in Tanzania (industrial scale). Both reach production costs of around 4 $/L, or roughly 4,000 $/ton oil. Figures from Optima of Africa Ltd. are based on two-year old Moringa trees. Considering that, at least in monoculture conditions, the yield is multiplied by three at maturity, one can expect a production cost of 2,500 $/ton oil (value that is still higher than the estimation of 1.53 $/kg oil given in table 1 for an industrial scale exploitation). As far as the MAFE project is concerned, seeds are collected from trees grown in fences (not in monoculture), and the figures obtained are also higher than the estimate of table 1 for a semi-industrial scale exploitation (2.07 $/kg). In both cases, oil production costs are expected to come closer to estimations through improving the seed yield and lowering the costs of seed production. Most importantly, the current production costs do not take into account any valorisation of the presscakes. This is the main reason why there are higher than the estimations given in table 1, which consider a valorisation of the presscakes as cattle feed at 0.15 $/kg.

Considering an average production cost of 2,500 $/ton, compared to the production cost of standard edible oils, like palm oil (150 $/ton) or sunflower oil (350 $/ton), it is obvious that Moringa oil in itself is much too expensive to be used as standard edible oil.
However, if we compare the production cost of Moringa oil to the selling price of cosmetics oils on the international market (Jojoba oil: 6,000 $/ton, Macadamia oil: 12,000 $/ton), Moringa oil appears to be competitive in this area. In addition, this market requires small amounts of product, which could primarily be satisfactorily provided by existing exploitations, before the demand raise and new exploitations develop.

HOW TO LOWER MORINGA OIL PRODUCTION COSTS TO TARGET THE EDIBLE OIL MARKET?

There are mainly two ways of lowering Moringa oil production costs. The first one is through the valorisation of the by-products of oil extraction, and the second one is through lowering the processing costs.

We have considered several ways of valorising the by-products. Note that these figures are to be taken with caution, since we calculated the market value of the by-product, without taking into account its production cost if any. Firstly, the presscakes can be used as fertiliser. The N/P/K ratio of the presscake is 22/3/4. This kind of fertiliser is sold around 5 $/50 kg on the international market. Considering a ratio oil/seed of 1:7 (see table 1, small motorised-scale), 6 tons of presscake is obtained per ton oil, which represents a potential of 600 $/ton oil and would lower the production cost to 1,900 $/ton Moringa oil.

Another way to use the presscakes is as fodder. However, due to the high oil content of the cake (directly related to the low oil extraction yield), this kind of cakes has a short lifetime and cannot be sold over 0.2 $/kg on the international market. Such utilisation would provide an additional value of 1,200 $/ton oil, which would lower oil production cost to 1,300 $/ton (note that this value is closer to the estimation of 1.53 $/kg given in table 1 for an industrial scale exploitation).
As a source of fuel, compared to firewood market price of around 15 $/ton, the presscakes could contribute to lower oil production cost by 90 $/ton, this one thus reaching 2,400 $/ton.
To be used in water treatment, the presscake in itself is not marketable because it is not an enough standardised product.

However, the flocculent proteins contained in the cake have a high marketable value. These soluble proteins represent 12.5% of the cake. The flocculent concentrate is obtained by milling the cake, soaking it in water and filtering it, the water extract being subsequently concentrated. According to Optima of Africa Ltd., which is currently the only one to produce this concentrate at a large scale, the production cost of the flocculent extract is 500 $/ton, that is to say 375 $/ton Moringa oil. The filter press can then be used as cattle feed. Depending on the selling price of this flocculent extract, such utilisation of the presscake would lower the production cost of oil by the difference between the selling price of the flocculent and its production cost. But here comes the point to know whether flocculent extraction is supposed to lower the production cost of oil, or on the contrary whether oil extraction is supposed to lower the cost of flocculent production! Actually, due to the low cost of alum on the international market, the latter option seems to be more realistic because Moringa flocculent extract is supposed to be competitive compared to alum.

In addition, one has to keep in mind that consistent investments have been necessary to produce an efficient flocculent (patented by Optima of Africa Ltd. as Phytofloc^{tm}), and that a large volume of

flocculent (5,000 ton/year) has to be produced for return on investment. To produce such an amount of flocculent, 60,000 tons of seeds are necessary, that is to say 20,000 ha of Moringa plantations.

Lowering oil production cost can also be achieved through the reduction of oil processing costs. The limiting steps of oil production are seed yield and oil extraction yield.

Seed production could be enhanced through genetic breeding, by improving both the seed yield and the oil content of seeds. There is quite a lot of genetic variability within and among Moringa species, and except in India for green pods production purposes, there has been almost no agricultural selection of Moringa. This means that there is a lot of work to do in that sense, and that good results can be expected. The successful experience of India with PKM1 and PKM2 cultivars, which have been selected for green pods yield, is promising for future improvements.

The other focal point of action is the improvement of oil extraction yield. Some pieces of research have already been carried out by several teams to adapt existing press with various results. However, we clearly think that a considerable international effort should be made in order to design a press specifically adapted to Moringa oil extraction.

TARGET MARKETS FOR MORINGA-DERIVED PRODUCTS

We have considered the potential market for Moringa products at different scales. At the local scale, Moringa products are very unlikely to meet a demand because they are rather expansive compared to locally used equivalent products or because there is no existing market for this kind of products.

At the national and regional scale, Moringa oil could substitute a small fraction of local edible oil, as a high quality (comparable to olive oil), locally produced oil. However, such market penetration would be possible only if the production costs are further reduced. The strategy of market penetration should be based on the very good quality of the oil (it is worth mentioning that in Tanzania, for instance, olive oil is sold 8 to 9 $/L) and on the fact that is it locally produced (in Tanzania, 90% of the edible oil is imported). It could also replace part of locally produced or imported cosmetic oil. In addition, Moringa flocculent extract could substitute a small part of the existing flocculent market (mainly alum, which is imported). Finally, the presscakes could penetrate the market of animal food.

At the international scale, the most promising outcomes are for Moringa oil in cosmetics and for Moringa flocculent extract. The main advantage of Moringa-derived flocculent is that it is environmentally friendly compared to the widely used alum. As far as oil is concerned, it has the great advantage, for cosmetic usage, in addition to its properties close to that of olive oil, to be extremely stable towards oxidation, and to be light-flavoured.

It has to be noted that if the international market is responding to Moringa products, there will be a need to increase the surfaces of Moringa plantations, and to extend its cultivation to other countries.

However, there are still a few major constraints to overcome before large-scale commercialisation is possible. The first one concerns the standardisation of the products, whether it is oil or flocculent. Indeed, depending on the origin of the trees and on the technologies used, there is quite a lot of variability in the quality of the products obtained. The second one is related to regulation: a lot of toxicological studies still have to be performed before the product is approved for commercialisation.

CONCLUSION

Finally, what comes out from this discussion is that there is a huge potential of development for Moringa products, especially for cosmetic oil and flocculent, both at the regional and international level. However, a lot of constraints still have to be overcome in order to allow large-scale production and commercialisation of these products.

From an agricultural point of view, a program of genetic breeding of *Moringa oleifera* should be launched to create cultivars specifically designed for seed and oil production.

From a technical point of view, the pressing technology should be optimised for the most effective extraction (is dehusking necessary? What is the optimal seed water content?) and a specific press should be designed to improve the extraction yield. Moreover, the alteration of oil quality during pressing (denaturation/oxidation of fatty acids), depending on the pressing conditions (temperature, type of press) should be studied in more details.

Concerning the standardisation of the products, a range of acceptable variations should be defined, and the origins of the trees grown and the different technologies used should be harmonised to meet this acceptable range of variations.

As far as regulation is concerned, toxicological studies have to be carried out for the different products (oil for edible and cosmetic use, flocculent, presscake for animal feeding). This kind of studies is generally expansive, and as several countries in East Africa are interested in the commercialisation of Moringa products, it would need regional/international co-operation, and should be funded by a world organisation for the benefit of all. Finally, some market studies would be necessary to evaluate the potential of development of Moringa products.

It has also been noticed that, although controversial, the "carbon credit" (which relies on the fact that polluting firms could promote tree plantations instead of paying taxes for their contribution to global warming) could finance Moringa plantations throughout the world.

Finally, one has to keep in mind that Moringa still has a huge potential of diversification, with various high-value products that can be extracted from the leaves, like luteins, □-carotene, fragrances, essential oils…

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