# Techno-economic assessment of the cultivation of turmeric in NW-Europe

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# 1. The CURCOL project

Packaging waste in Europe amounts to 87 million Mts/year (2016), of which circa 41% is paper/carton and 19% plastics. Of the plastic packaging less than 50% is currently recycled. The "plastic soup" and other environmental problems raise increasing demands to make packaging more sustainable and recyclable. The packaging manufacturing is in need of sustainable materials to address changing customer needs. The challenge is to make the complete packaging industry sustainable and future-proof. CURCOL aims to provide biobased colorants to assist the packaging industry in the region to make a transition to fully biobased, environmentally friendly products. Current biopackaging is circa 2 % of the packaging, but the share is growing very fast.

CURCOL also addresses the needs of horticulture in the Northwest Europe-region (NWE). The increasing global competition is decreasing the profits of traditional production. Simultaneously the demand for energy savings and environmental control increases. The sector requires innovation in high value crops and transition to new technologies. CURCOL demonstrates the innovative turmeric cultivation to stimulate the innovation and maintain the local production capacity of NWE horticulture. Horticulture is of high economic importance in Belgium and the Netherlands, and the countries are leading innovation in the field. The practices in other NWE regions tend to be more traditional, these countries can benefit of transfer of these new insights.

In this techno-economic analysis we specifically evaluate the cost-effectiveness of cultivating turmeric in the region of Northwest Europe. Based on data of the trial cultivations in previous years and the process flows, an economic evaluation of different techniques and processes is done. We introduce the base case, as well as two reference cases and the assumptions used to do our calculations. In the third chapter we describe the results for the cases. We end this report with the main conclusions.

# 2. Turmeric cultivation

## Base case

In the base case of 'Turmeric cultivation' we evaluate the techno-economic feasibility of cultivation of turmeric in an unheated plastic tunnel in NW-Europe, starting from purchased plants.

For the model we make maximal use of the data that is available from the trials that are performed at PCG, combined with some assumptions. A tunnel crop of turmeric can be grown on ridges 60 cm wide with a row spacing of 30 cm and a planting distance of 25 cm, resulting in a planting density of 13,3 plants per m². In this base case, we start with purchased plants of a variety that we call 'Claus'. The genetic origin of plant material is not always clear and not a lot of subtypes are documented. Today, no locally raised plant material is available, the plants have yet to come from abroad (in this case, southern Europe). We assume that growers on average have a plastic tunnel of 250 m² of which 50 % of the tunnel is occupied by the ridges on which the turmeric grows. The soil in the tunnel is prepared: fertilization is incorporated, ridges (with drip tape) and plant holes are made. In addition, overhead sprinkling is also provided, if it was not already present. Plants are planted out between the end of April and the end of May. Mulching is then done with green compost to promote growth, reduce weed growth and ensure moisture in the ridge. Irrigation is applied, more intensively on warm days than on cold days. If necessary, weeds are weeded and mulching is applied a second time during cultivation. Flowers can be harvested after 5 months.

After around 7 months, also fresh rhizomes can be harvested. A harvest of around 503 grammes per plant or 6,77 kg fresh rhizomes per m² can be obtained. The rhizomes can be sold fresh, but that

market segment is not so big. The rhizomes can be dried and ground so that turmeric powder can be marketed. The extraction of curcumin(oids) out of the rhizomes can add value. The valorization of the foliage has been investigated by several researchers (Braga, 2018). The biggest opportunity lies in the curcumin contained in the turmeric plant. This variety grown in a tunnel cultivation contains about 1,5 % of curcumin. Through extraction and purification, curcumin powder can be produced. This powder can be used in the dye, food, and medical industries.

A schematic representation of the base case process flow is provided in Figure 1.

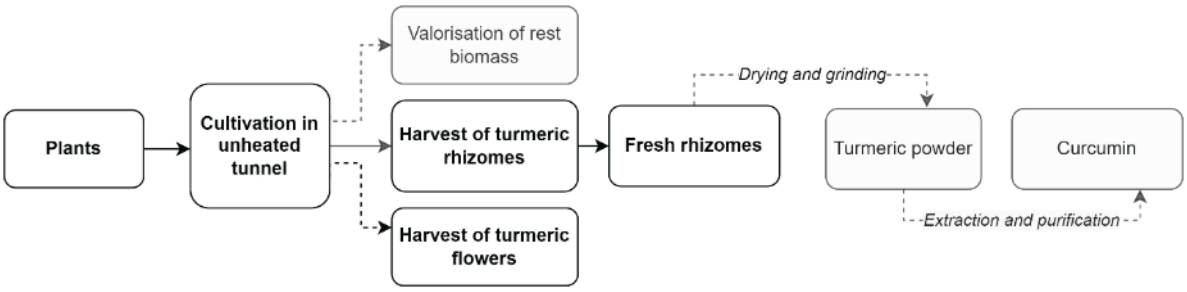


*Figure 1: Process flow - base case*

Based on this process, a cost-effectiveness study is performed. For simplicity and because this will always be a rather small cultivation for growers, no interest or other capital costs are taken into account. Table 1 lists the assumptions and known costs used for estimating the operating and maintenance costs. The costs for fertilizers, plant protection products and materials such as irrigation equipment, for example, were calculated based on the usage data of three years of turmeric cultivation at the research center in Belgium. The depreciation of the classic plastic tunnel is assumed over 10 years. The cost of water is also based on the average water consumption of a tunnel turmeric crop, which is 350 liters per m², combined with the water consumption for the cleaning of the rhizomes. Energy consumption is not applicable in this unheated tunnel. The last and largest cultivation cost is the planting material. Over two years, an average price of € 1,85 per organic turmeric plant was paid, this concerns P11 plantlets. For labour costs, time records of the different operations were made during the different cultivations. These were settled to a time estimate per m².

*Table 1: Operational costs of a turmeric tunnel cultivation.*

| **Cultivation costs** | | |
|---|---|---|
| Fertilizers and crop protection products | 0,30 | €/m² |
| Equipment | 3,48 | €/m² |
| Water | 0,12 | €/m² |
| Energy | 0,00 | €/m² |
| Plant material | 24,61 | €/m² |
| **Labour costs** | | |
| Soil operations and ridge pulling | 0,43 | €/m² |
| Pregermination | 0 | minutes/m² |
| Plant | 7 | minutes/m² |
| Weed control | 2 | minutes/m² |
| Harvest and cleaning | 35 | minutes/m² |
| Staff cost seasonal worker | 15 | €/hour |

The combination of the cultivation costs and the labour costs provides the total operational costs or the total production cost. This can be translated into the minimum selling price (MSP) of the turmeric rhizomes. The formula for the calculation of the MSP is provided in the equation below.

$$MSP = \frac{total\ production\ cost\ (€/m^2) - revenues\ byproducts\ (€/m^2)}{product\ yield\ (kg/m^2)}$$

The biggest revenue stream comes from the turmeric rhizomes and its curcumin content. The total yield of rhizomes (net weight) in tunnel is 6,77 kg/m². Taking into account that about 50 % of the tunnel is filled, we arrive at a yield of 3,385 kg/m² for an entire tunnel. In addition to this main product, the by-products flowers and foliage also have economic value. Though not significant, the revenue obtained by selling the by-products could offset some of the production costs. As mentioned before, the valorization of the foliage has been investigated by other researchers (Braga, 2018). However, the economic potential of this value chain is missing in the literature. For now, this valorization has not yet been further developed, but this is certainly an interesting, potentially additional source of income.

Another by-product of this cultivation is the beautiful flower. Flowering is not guaranteed, but our observations lead us to conclude that, on average, a quarter of the plants (across all varieties) produce a beautiful flower that can be sold. For now, no flowers of *Curcuma longa* are on the Belgian market, presumably not on the European market either. There are, however, similar flowers of *Curcuma siam* on the market and its average market price is € 0,87 per flower (Euroveiling auction, personal communication, January 23, 2023 and Maenhout, M., personal communication, January 17, 2023). People from flower auctions and other florists confirm that the flowers of *Curcuma longa* also have potential to be used as cut flowers, especially if grown locally. This assessment was performed to identify whether the cultivation of turmeric in an unheated, plastic tunnel would be profitable under these data and assumptions.

### Reference case 1

In reference case 1 of 'Turmeric cultivation' we evaluate the techno-economic feasibility of cultivation of turmeric in a heated greenhouse in NW-Europe, using pre-germinated plants.

For the model we make maximal use of the data that is available from the trials that are performed at PCG, combined with some assumptions. For reasons of accessibility, flat-field cultivation is required in most soil-bound heated greenhouses. Here, a standard greenhouse of 400 m² is taken into account, with beds 1 m wide. With the same planting distances as in the base case, the planting density becomes only 8 plants per m². Around 66 % of the greenhouse is occupied by turmeric plants. In this reference case 1, we do not start with purchased plants, but with saved planting material that the grower pre-germinates himself. It does involve the same *Curcuma longa* L. variety that we call 'Claus'.

Pre-germination involves cutting the rhizomes, which are then air-dried. They are then planted out in potting soil and pre-germinated at high humidity and temperature. It is these pre-germinated plants that can then be planted out in the greenhouse as early as March. Otherwise, cultivation is the same as in the tunnel. Besides maintenance, mulching and irrigation, the greenhouse is also heated to a 24-hour temperature of more than 25 °C. Consequently, more irrigation is needed than in a tunnel crop. Flowers can be harvested after 5 months.

After around 7 months, also fresh rhizomes can be harvested. A harvest of around 890 grammes per plant or 8,90 kg fresh rhizomes per m² can be obtained. When grown in a heated greenhouse, this variety contains more curcumin, about 3 %. This is of course interesting later in the chain.

A schematic representation of the reference case 1 process flow is provided in Figure 2.

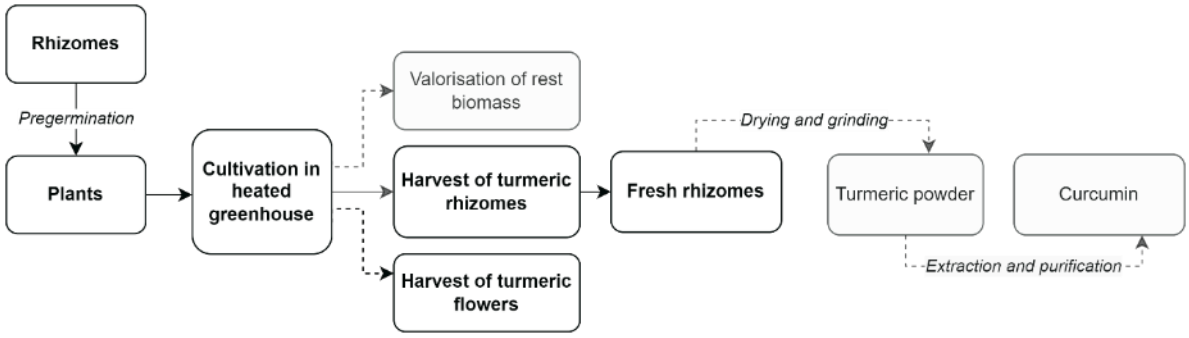


*Figure 2: Process flow - reference case 1*

Based on this process, a cost-effectiveness study is performed. For simplicity and because this will always be a rather small cultivation for growers, no interest or other capital costs are taken into account. Table 2 lists the assumptions and known costs used for estimating the operating and maintenance costs of this greenhouse cultivation. Only the differences with the base case are briefly touched upon. The depreciation of the greenhouse is assumed over 10 years. The cost of water is based on the average water consumption of a greenhouse turmeric crop, which is 527 liters per m², combined with the water consumption for the cleaning of the rhizomes. The cost of the planting material is estimated by taking into account the cost of rhizomes, trays and potting soil.

*Table 2: Operational costs of a turmeric greenhouse cultivation with pre-germination.*

| **Cultivation costs** | | |
|---|---|---|
| Fertilizers and crop protection products | 0,30 | €/m² |
| Equipment | 3,46 | €/m² |
| Water | 0,17 | €/m² |
| Energy | 42,23 | €/m² |
| Plant material | 6,00 | €/m² |
| **Labour costs** | | |
| Soil operations | 0,10 | €/m² |
| Pregermination | 0,4 | minutes/m² |
| Plant | 7 | minutes/m² |
| Weed control | 2 | minutes/m² |
| Harvest and cleaning | 35 | minutes/m² |
| Staff cost seasonal worker | 15 | €/hour |

The last and largest cultivation cost in this reference case 1 is energy. Heating the greenhouse constantly to those high temperatures requires a lot of gas. To represent gas consumption, the average gas consumption of the different turmeric crops in a heated greenhouse was taken. Combined with the average (high) gas price in Belgium in 2022 of € 0,139 per kWh (VREG, 2023) this represents a huge cost. This reference case 1 also involves the extra energy input for pre-germinating the rhizomes. For labour costs, time records of the different operations were made during the

different cultivations. These were settled to a time estimate per m². Extra labour costs were taken into account for pre-germination.

This again can be translated into the minimum selling price (MSP) of the turmeric rhizomes by using the preceding equation. The same income streams as in the base case also apply in this reference case 1. However, it is important to take into account the additional yield of rhizomes. The total yield of rhizomes (net weight) in a heated greenhouse is 8,90 kg/m². Taking into account that about 66 % of the greenhouse is filled, we arrive at a yield of 5,874 kg/m² for an entire greenhouse. More importantly, rhizomes from a greenhouse cultivation also have a significantly higher curcumin content of 3 %. These data lead to an MSP that can reflect whether growing turmeric in a heated greenhouse would be profitable under these data and assumptions.

### Reference case 2

In reference case 2 of 'Turmeric cultivation' we evaluate the techno-economic feasibility of cultivation of turmeric in a tunnel cultivation in NW-Europe, using pregerminated plants and a variety with a higher curcumin content.

For the model we make maximal use of the data that is available from the trials that are performed at the research center, combined with some assumptions. A tunnel crop of turmeric can be grown on ridges 60 cm wide with a row spacing of 30 cm and a planting distance of 25 cm, resulting in a planting density of 13,3 plants per m². Saved planting material is pre-germinated. After soil preparation and ridge pulling, these plants are then planted between the end of April and the end of May. The same cultivation operations and harvesting results are observed as in the base case. However, it should be possible to grow a variety that, even in tunnel, can produce at least a curcumin content of 3%.

A schematic representation of the reference case 2 process flow is provided in Figure 3.

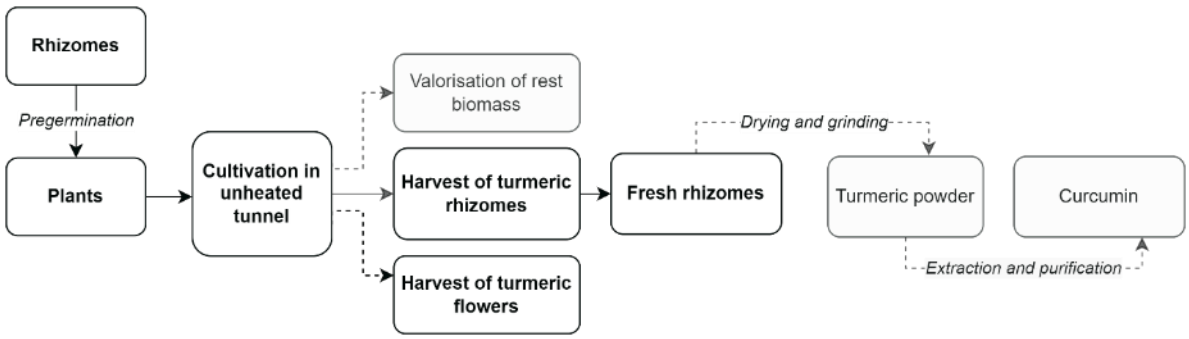


*Figure 3: Process flow - reference case 2*

Based on this process, a cost-effectiveness study is performed. For simplicity and because this will always be a small cultivation for growers, no interest or other capital costs are taken into account. Table 3 lists the assumptions and known costs used for estimating the operating and maintenance costs of this reference case 2 cultivation. Only the differences with the base case are briefly touched upon. These are the costs linked to pre-germination: the reduced cost of the planting material, the slightly higher labour costs and an energy cost (pre-germination takes place in the still cold months of March and April).

*Table 3: Operational costs of a turmeric tunnel cultivation with pre-germination.*

| **Cultivation costs** | | |
|---|---|---|
| Fertilizers and crop protection products | 0,30 | €/m² |
| Equipment | 3,48 | €/m² |
| Water | 0,12 | €/m² |
| Energy | 2,23 | €/m² |
| Plant material | 9,98 | €/m² |
| **Labour costs** | | |
| Soil operations and ridge pulling | 0,43 | €/m² |
| Pregermination | 0,67 | minutes/m² |
| Plant | 7 | minutes/m² |
| Weed control | 2 | minutes/m² |
| Harvest and cleaning | 35 | minutes/m² |
| Staff cost seasonal worker | 15 | €/hour |

This again can be translated into the minimum selling price (MSP) of the turmeric rhizomes by using the preceding equation. The same income streams as in the base case also apply in this reference case 2. We assume the same rhizome yield of 3,385 kg/m² for an entire tunnel, and a curcumin content of 3 %. These data lead to an MSP that can reflect whether growing turmeric in an unheated tunnel with pregerminated plants would be profitable under these data and assumptions.

# 3. Results

In this chapter the results of the assessment for the three cases are described, i.e. (1) base case tunnel cultivation, (2) reference case 1 greenhouse cultivation with pre-germinated plants and (3) reference case 2 tunnel cultivation with pre-germinated plants and variety with higher curcumin content.

## Base case

Figure 4 shows the cost breakdown of the total production cost of a tunnel cultivation with purchased plants. For the base case, the total production cost is € 39,51 per m². The major contribution to this cost comes from the plant material. Over 2 years, an average price of 1,85 euros per organic turmeric plant was paid, this concerns P11 plantlets. A possible way to reduce this cost item is proposed in reference case 1: pre-germination of the plants. Next to that, labour costs contribute around 28 % of the overall production costs. To reduce this, better mechanisation of cultivation must be sought. Especially in planting, harvesting and washing, time gains are certainly still possible, provided that the right mechanisation equipment is developed. The cost of energy is not applicable and the cost of water is almost ignorable in this case.

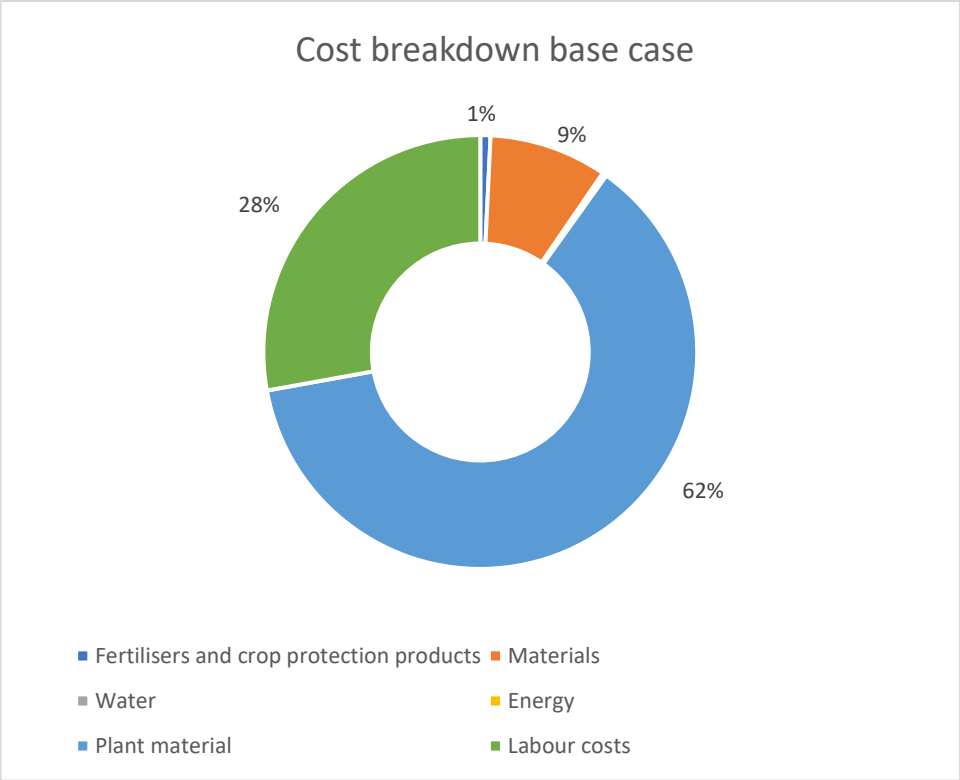


*Figure 4: Cost breakdown base case.*

The revenue of the by-products (flowers) is calculated by using the number of flowers per plant (0,25), the plant density (13,3 plants per m²) and the market price of the flowers (€ 0,87 per flower). This results in a by-product revenue of € 2,89 per m². We calculate the MSP using the preceding equation:

$$MSP = \frac{€\ 39{,}51\ /m^2 - €\ 2{,}89/m^2}{3{,}385\ kg/m^2} = €\ 10{,}82\ /kg$$

The average daily price of commonly grown turmeric on the world market is € 7,4 per kg (Commodityonline (2023), Tridge (2023)). Thus, the MSP of locally grown turmeric is substantially higher. However, the higher price of this turmeric can possibly be justified by the fact that it is organically grown and especially by the fact that it is a locally grown crop. Of course, the potential also lies mainly in reducing the high production costs, definitely those of the plant material. More and more local plant breeders are starting to show interest in growing turmeric plants, which will certainly also reduce the price per plantlet in the future.

Another opportunity to gain more profit from turmeric tunnel cultivation lies in the further processing of the rhizomes. High-quality turmeric powder or even pure curcumin is more valuable in the international market. Table 4 shows the potential revenue streams associated with cultivation in tunnel. Further processing naturally also requires more operations (thus costs) such as drying, grinding and extraction of curcumin. We have taken into account a return of 90 % when drying and grinding the rhizomes into turmeric powder. The extra costst are not calculated because it seems less suitable to be carried out by the growers. Still, it is interesting to keep the value of curcumin in mind especially.

*Table 4: Possible revenue streams from turmeric tunnel cultivation*

| Possible revenue streams tunnel cultivation | | | Reference |
|---|---|---|---|
| *Fresh rhizomes* | | | |
| Yield | 3,39 | kg/m² tunnel | |
| Price | 7,40 | €/kg | Commodityonline (2023), Tridge (2023) |
| *Turmeric powder* | | | |
| Possible yield | 3,05 | kg/m² tunnel | |
| Price | 2,81 | €/kg | Booker et al. (2012) and Special Fruit, personal communication, January 11, 2023 |
| *Curcumin* | | | |
| Possible yield | 0,05 | kg/m² tunnel | |
| Price | 518,53 | €/kg | Pomona Aroma B.V., personal communication, January 23, 2023 |
| *Flowers* | | | |
| Yield | 0,25 | flowers/plant | |
| Price | 0,87 | €/flower | Euroveiling auction, personal communication, January 23, 2023 and Maenhout, M., personal communication, January 17, 2023 |
| *Foliage* | | | |
| Yield | 3,2 | kg/m² tunnel | |
| Price | ? | €/kg | |

### Reference case 1

Figure 5 shows the cost breakdown of the total production cost of a tunnel cultivation with purchased plants. For reference case 1, the total production cost is € 63,26 per m². The major contribution to this cost (67 %) comes from the energy consumption of the cultivation. Intensive heating and an annual price of 2022, a year when gas prices were historically high, were calculated. But anyway, the energy consumption of a heated greenhouse cultivation of turmeric will always be the biggest cost. Of course, this is also accompanied by an increased yield (and also an increased yield of curcumin). The MSP is calculated using the preceding equation:

$$MSP = \frac{€\ 63{,}26\ /m^2 - €\ 1{,}74/m^2}{5{,}874\ kg/m^2} = €\ 10{,}47\ /kg$$

Combined with the yield of the flowers and cultivating at a lower plant density in the greenhouse, we arrive at an MSP of organic turmeric rhizomes of € 10,47 per kg. Very similar to the base case, a tunnel cultivation with purchased plants.

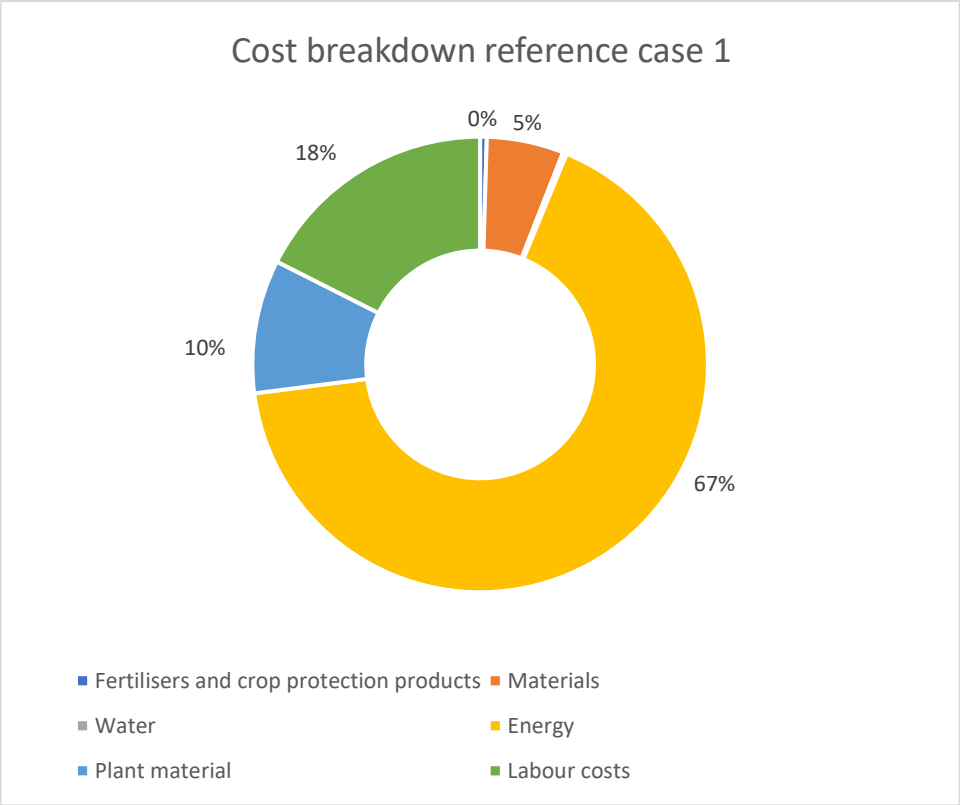


*Figure 5: Cost breakdown reference case 1.*

Compared to the market price of € 7,4 per kg, the MSP is thus very high. Apart from the possible extra price for organic, locally grown turmeric, there is still work to be done here too to reduce costs. Growing at lower temperatures (with reduced gas consumption) is an option, but then yields will also drop. This certainly needs to be taken into account. Therefore, in these times of global warming, heating a greenhouse does not seem a valid way-to-go. Even the increased yield of curcumin does not seem to be sufficient. Table 5 shows the additional yields of rhizomes, turmeric powder and curcumin and the possible revenue streams. Again, these have not been elaborated further as they seem less applicable to be implemented by a grower.

*Table 5: Possible revenue streams from turmeric greenhouse cultivation*

| Possible revenue streams greenhouse cultivation | | | Reference |
|---|---|---|---|
| *Fresh rhizomes* | | | |
| Yield | 5,87 | kg/m² greenhouse | |
| Price | 7,40 | €/kg | Commodityonline (2023), Tridge (2023) |
| *Turmeric powder* | | | |
| Possible yield | 5,29 | kg/m² greenhouse | |
| Price | 2,81 | €/kg | Booker et al. (2012), Special Fruit, personal communication, January 11, 2023 |
| *Curcumin* | | | |
| Possible yield | 0,18 | kg/m² greenhouse | |
| Price | 518,53 | €/kg | Pomona Aroma B.V., personal communication, January 23, 2023 |
| *Flowers* | | | |
| Yield | 0,25 | flowers/plant | |
| Price | 0,87 | €/flower | Euroveiling auction, personal communication, January 23, 2023 and Maenhout, M., personal communication, January 17, 2023 |
| *Foliage* | | | |
| Yield | 5,45 | kg/m² greenhouse | |
| Price | ? | €/kg | |

## Reference case 2

Figure 6 shows the cost breakdown of the total production cost of a tunnel cultivation with pregerminated plants. For reference case 2, the total production cost is € 27,27 per m². In this case, the labour cost is the biggest cost. As already mentioned in the base case, this cost can be reduced through mechanisation. But a total production cost of € 27,27 per m² does provide opportunities for an interesting MSP, as demonstrated below. We calculate the MSP using the preceding equation:

$$MSP = \frac{€\ 27{,}27\ /m^2 - €\ 2{,}89/m^2}{3{,}385\ kg/m^2} = €\ 7{,}20\ /kg$$

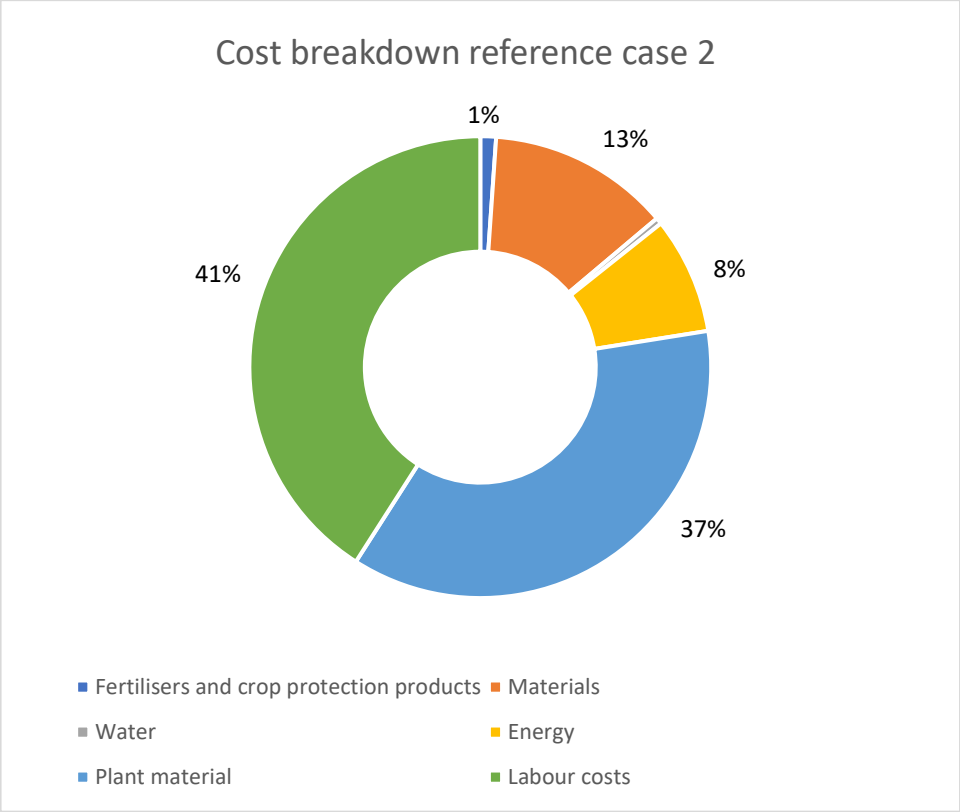


*Figure 6: Cost breakdown reference case 2.*

This minimum selling price hovers around the current market price of € 7,40 per kg, so this offers opportunities. Next to that, the same possible revenue streams as in the base case are present.

### Impact of scale

For all previous cases, there is an impact of scale. The cases have been worked out for a small (tunnel of 250 m² and greenhouse of 400 m²) but realistic scale. Certain operational costs such as equipment will become cheaper per m² when scaling up, as will labour costs. However, the high yield per m² ensures that growers will already be able to harvest a large volume of rhizomes at this small scale. Growers will therefore probably not scale up quickly. Hence, no further analysis was conducted around the impact of scale.

## 4. Conclusion

The base case is how growers in Northwest Europe best approach cultivation in the first few years. Cultivation can be done easily and at relatively low cost. The minimum selling price is significantly higher than the current market price, but with good marketing and consumer awareness it should be possible to get a higher price than the current market price for this local, organic turmeric.

It is important to note, though, that in past warm years, yield results were very good, in our temperate climate. Perhaps yield results are still a bit disappointing in a colder year. To be sure of a high yield, for instance to a buyer, reference case 1 can be applied. Provided good agreements are made with the buyer, it should certainly be possible to exceed the MSP.

Eventually, the aim should certainly be to move more towards the process flow of reference case 2, or cheaper plants should become available on the European market. In any case, the future does look bright, provided further research into curcumin content, pre-germination and mechanisation.

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