FLONUDEP

Promotion of sectors engaging in sustainable development

using a decision support tool

Environmental sustainability, nutritional quality, socio-economic impacts in the fruit and vegetables sectors: a closer look at the tomato

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For more information, please visit the FLONUDEP Project website: http://flonudep.iamm.fr

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1 Introduction

1.1 Background

Agriculture is central to the concept of sustainable development due to its multi-functional character encompassing the full range of ecological, nutritional, economic and social functions. This concept is still open to debate and while the environmental dimension continues to predominate, it has expanded to take in other dimensions through, for example, corporate social responsibility (CSR).

The consumption of fruits and vegetables (F&V) in France is deemed to be insufficient in comparison to international recommendations, with an average consumption per person per day of 380g compared to the 400g suggested. Although this average is close to recommendations, it hides inequalities in consumption. For instance, just 43% of adults and only 20% of children meet the National Health and Nutrition (PNNS) guidelines. The consequences of this for the sector are considerable and are likely to worsen given generation-related effects over time (at the same age, we consume less and less F&V than in the past). Furthermore, consumer information remains confused. Price, nutritional quality, social or environmental performance are among key pieces of information guiding the choice of the consumer.

These sustainability criteria are part of the regulatory framework which every professional must abide by. Although prices and nutritional labelling are already mandatory and standardised Europe-wide (as defined in European Regulation n°1169/2011[1], energy content and levels of 6 nutrients (total fat, saturated fats, carbohydrates, sugars, proteins and salt), environmental information has to be mainstreamed following the decision in 2013 of the French National Consumer Council and the Parliament in 2013. "Concrete proposals" have been sent to the National Council for Ecological Transition. On a European level, standardisation of Life Cycle Assessment methods for food products is being studied as well as different methods of consumer labelling (ENVIFOOD Protocol).

The horticultural sectors are increasingly being challenged (greenhouse gas production, labour exploitation, local economies being destroyed, etc.). Yet, these high value products represent development opportunities that must be seized. The socio-economic challenge is sizeable since the sector is subject to strong competition from emerging economies, particularly due to their low labour costs. As a large consumer of manpower, this sector has still managed to establish jobs in a region. Making better use of the advantages French producers enjoy could help revitalise this market. In terms of health, F&V play a vital role through their nutritional density. According to the World Health Organisation (WHO), 207 million deaths annually in the world could be prevented by an adequate consumption of F&V. Since 2001, in France as in many other countries worldwide (FAO/WHO PROFEL initiative), the PNNS puts F&V at the heart of its dietary recommendations. It is often considered that France does not do as well as it could in terms of environmental impacts. Intensive production using glasshouses (80% of French production) represents a major handicap in terms of its carbon footprint. This raises questions about working conditions in the F&V industry. Faced with this reality, the industry is the source of numerous technical and organisational innovative techniques (sustainable glasshouses and restructuring logistical flows respectively). But, the fact remains that farming techniques used in France could significantly penalise French producers if the environmental parameter was taken into consideration. Giving consideration to other parameters such as social, economic, or nutritional criteria could constitute a new pathway for promotion and development.

The professionals who are keen to satisfy their customers nevertheless see mounting constraints. They appear to have little power in ensuring that the consumer has an optimal combination of nutritional, environmental and social pieces of information, or in their decision to favour one factor over another.

[1] *Regulation (EU) n° 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers*

Any decision to reorganise their activities can have significant consequences on the future of their business. They therefore need a decision support tool to efficiently organise the industry, identify critical points, and to serve as a basis for discussion between industry stakeholders as required. The purpose of the FLONUDEP Project was precisely to create a decision support tool for a more sustainable, multidimensional food system for professionals working in the industry. This tool makes it possible to simultaneously analyse a food business sector from both and environmental, social and nutritional standpoint.

1.2 Scope of application

The present document was written by consensus and describes the approach, the methodological tools to establish sustainable supply chains and the indicators that can be used to assess sustainability (to the meaning of Sustainable Development) of a product from the horticultural sector All the data, analyses and conclusions from the FLONUDEP Project are presented in summary form.

The industry's sustainability is measured according to its impacts on the environment, the nutritional quality of the foodstuff and the prevailing social and economic conditions in the sector or the company. The project considers the whole supply chain from the farm to the consumer.

These indicators will:

- help the professionals working in the industry to assess the consequences of altering their production processes or their organisation based on 3 sustainability priorities for their product by eventually using the decision support tool described in paragraph 6;
- help authorities target their policies to manage the sector (regulations support/assistance, etc.)
- provide the consumer with objective information on the product they are buying to make purchasing decisions.

1.3 Limits of application

The FLONUDEP study focuses on the tomato which is considered to be a generic product. This is the most-consumed fruiting vegetable in France with an average consumption of 15 kg/capita/yr of fresh tomatoes (source: INCA 2[2]) and 18.4 kg/capita/yr of processed tomatoes (WPTC, 2012[3]). It constitutes an interesting study example because of the wide range of growing methods used (glasshouse, soilless culture, open field cultivation), the geographical origins, either close by or far-off (fresh tomatoes from Europe or Morocco, processed tomatoes from Europe, China, Turkey), a wide range of products marketed and subsequent forms of agri-food technology used to obtain processed products.

The study was limited to France, Morocco and Turkey. Morocco was chosen as France's leading business partner in the trade of fresh tomatoes (France accounts for 84% of EU-bound exports from Morocco). Turkey, on the other hand, only exports small quantities of tomatoes processed in France although it is the world's 4th biggest producer of tomato paste and can therefore quickly become a competitor to the main exporting countries of Italy and Spain. One quarter of the Turkish tomatoes are grown for processing. These countries also feature specific socio-economic contexts and social institutions.

[2] *Individual and National Study of Food Consumption 2 Report (INCA 2) (2006-2007), Sept. 2009, AFFSA/ANSES*
[3] *WPTC: World Processing Tomato Council (www.wptc.to/)*

As concerns product type, the study focused exclusively on the most common products on the market:

- French round glasshouse tomatoes (96% of fresh tomatoes are grown in glasshouses and the most common tomato on the French market is the round vine tomato),
- Moroccan open field round tomatoes grown under plastic (100% of tomatoes for export are grown under plastic and 83% of tomatoes exported to France are round),
- Tomato paste produced in Turkey (flagship product of Turkish production), tomato paste produced in France (1st stage processing) and basic tomato sauce (2nd stage processing) produced in France.

2 A unique methodological approach: Life Cycle Assessment as a common thread in evaluating three component parts

The Life Cycle Assessment method (LCA) has been used as the common thread to combine different aspects of sustainable development in a systemic analysis of the sectors. It is proposed as a coherent and inclusive framework for the environmental, nutritional and socio-economic dimensions.

LCA was originally a method for assessing a product's environmental impact, from its design right through to the end of its life. It is a standardised method and has been formally adopted by ISO standards 14040 to 14043[4]. According to these standards, "*LCA is tool to assess the environmental impacts of a system, including all activities linked to a product or service from raw material acquisition to disposal and waste treatment"*. This method makes it possible to quantify, understand, evaluate and analyse all potential environmental impacts (resource extraction, land use, greenhouse gases, acidification, eutrophication, etc.) "throughout the life cycle of a product, from raw material acquisition and its production, use, end-of-life treatment, recycling and disposal". This is what is referred to as a "cradle-to-grave" approach.

For information on social performance, ISO standard 26000[5] is the current benchmark. In article 4 of this standard, it states that organisations must give consideration to their ethical behaviour while respecting stakeholder interests, the principle of equality and international standards in labour rights and human rights.

LCA consists of 4 basic stages: (i) Goal and scope definition, (ii) Inventory, (iii) Assessment, (iv) Interpretation. These are shown diagrammatically in Figure 1 below.

Stage i **Defining the study's goal and scope** highlights the topic, the anticipated applications and identifies the study's recipients. System boundaries, the functional unit and the underlying assumptions, particularly in terms of allocation rules, are all defined here.

Stage ii The **inventory** corresponds to quantifying all the material and energy flows entering and leaving the system for each basic process.

Stage iii The **assessment** of potential impacts linked to these incoming and outgoing flows makes it possible to convert and aggregate the inventoried flows in different environmental impact indicators and/or damage using factors characterising these impacts.

Stage iv The **interpretation** consists of analysing the results obtained from the data collected as well as the underlying assumptions, especially in relation to the system's boundaries. Analysing sensitivity helps to assess the effect certain key parameters have on the results.

[4] *NF EN ISO 14040:2006 Environmental management – Life Cycle Assessment – Principles and Framework*
NF EN ISO 14041:1998 Environmental management – Life Cycle Assessment – Goal and Scope Definition and Inventory Assessment
NF EN ISO 14042:2000 Environmental management – Life Cycle Assessment – Life Cycle Impact Assessment
NF EN ISO 14043:2000 Environmental management – Life Cycle Assessment - Life Cycle Interpretation

[5] *NF ISO 26000:2010 Guidance on Social Responsibility*

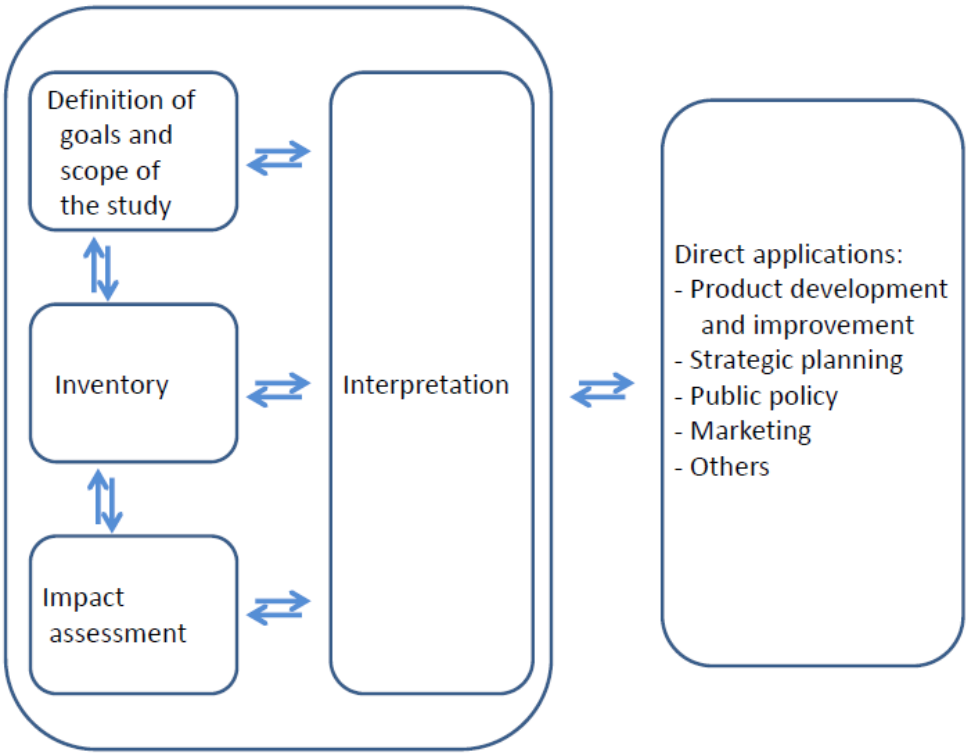


Figure 1: LCA methodological framework: the four stages of a LCA (ISO 14040:2006)

LCA can help companies make decisions on choices of products and procedures. It is an integrated approach that makes it possible to measure company performance and to compare products.

Life cycle assessment therefore provides advantages to different stakeholders in various sectors. By building in this type of approach, professionals can take action in the production process stages or the sector having the greatest impact and subsequently improve their company's strategic position and image. For their part, governments can ensure environmental benefits for society by supporting sustainability programmes and initiatives that also give consideration to economic and social aspects. Finally, consumers will be better informed and better able to choose more sustainable forms of consumption, greener transport and energy sources having less impact, etc. This type of life cycle assessment approach will also enable the creation of a platform for discussion and exchange between the different stakeholders for sustainable development at both local and national level.

The innovative nature of this type of approach is in exploring new less-apparent arguments to make them more visible and accessible to consumer knowledge. In France, F&V still enjoy a positive healthy image capital and the health argument is probably not the only way of promoting them. FLONUDEP shows that other arguments (social, economic) are possible and that improvements can be made in terms of the environment.

3 Environmental impact assessment

The environmental impacts that are considered to be relevant and meet with consensus for food products are those focusing on:

- **global warming**, due to greenhouse gases (GHG) (mainly carbon dioxide (CO_2), ozone (O_3), methane (CH_4) and nitrous oxide (N_2O) which is expressed in CO_2 equivalent;

- **water quality,** in its qualitative aspects (aquatic eutrophication and ecotoxicity for which the main culprit is nitrogen in the form of nitrate, phosphorus in the form of phosphates and pesticides, etc.) and in quantative terms (contribution to diminishing water resources and environmental impact);
- **biodiversity**, for which the assessment method is still subject to debate.

Other impacts also appear relevant such as those concerning:

- **acidification**, rising acidity in soils, water courses or the atmosphere due to human activity can alter the chemical and biological equilibriums and gravely affect ecosystems. Atmospheric acidity is measured in pH and mainly caused by sulphur dioxide emissions (SO2), nitrogen oxides (NOx) and ammonia (NH3). Acid rain comes from this;
- **human toxicity potential**, which reflects the potential harm to human health from chemical products released into the atmosphere and the environment.

3.1 The case of the "out-of-season fresh tomato consumed in France"

3.1.1 Goal and scope of study

Applying LCA to out-of-season fresh tomatoes consumed in France had the twin goal of comparing all the environmental impacts of tomatoes produced in Morocco and in France for the French market and of identifying the critical points in these two sectors. The system studied includes all the life cycle stages (cradle-to-grave) from producing and transporting tomato plants, agricultural inputs (fertilizers, plant protection products, etc.), agricultural production, storing tomatoes, all stages of transport and logistical management and the consumption stage (Figure 2).

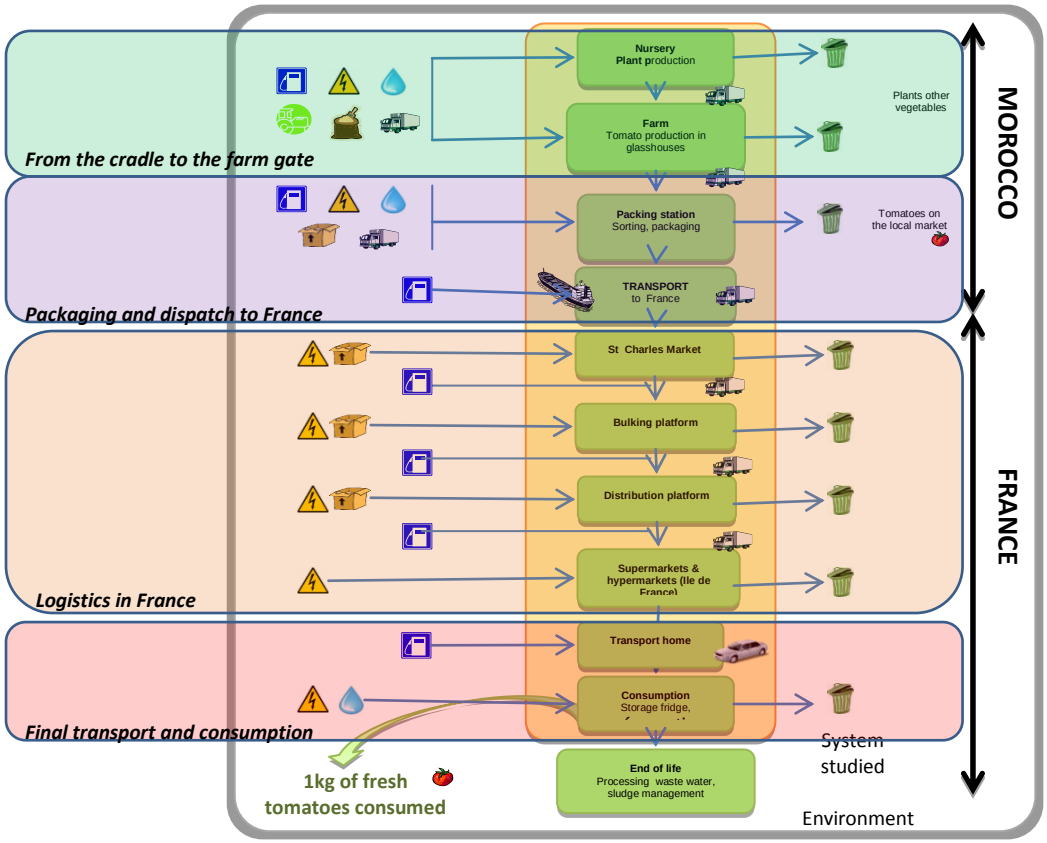


Figure 2: System studied for fresh tomatoes produced in Morocco and consumed in France

Environmental impacts are expressed in kg of tomatoes at the consumer level (this is the functional unit).

3.1.2 Life cycle inventory of the out-of-season tomato

In Morocco, tomatoes for export are produced in the region of Souss and grown in the soil in unheated polytunnels. In France, out-of-season tomatoes are mainly produced in the South East and North West regions in soilless heated glasshouses or polytunnels.

As part of the project, a very detailed survey for Moroccan tomatoes was conducted with 3 farms in the region of Souss over 3 growing seasons (2008 to 2010). For French tomatoes, LCA "from the cradle to the farm gate" calculations performed by the INRA team from Sophia Antipolis as part of the NRA Ecoserre Project were used. This work is based on typical French production scenarios designed essentially from expert contributions. Apart from their geographical situation, the main differences between the two types of systems lie in the use of more intensive inputs per hectare for the French systems in terms of fertilizers, water consumed, the growing substrate, infrastructure and especially heating. Logically, yields from the French systems are also higher (250 - 500t/ha compared to 210 for the sample studied in Morocco).

For both industries, assessment of the packaging, transport and logistics and consumption stages beyond the farm gate was specifically conducted as part of the project. Surveys with different stakeholders helped design and assess average scenarios for all the stages. The environmental inventory of inputs used by the various life cycle stages was taken or adapted from databases available from the ACV SIMAPRO software, particularly the Ecoinvent database.

3.1.3 Environmental impact assessment

To assess environmental impacts, we used the ReCiPe (Hierarchical) method combined with Pfister et al's method[6] for those water use-related impacts. "Climate change within 100 years", "eutrophication potential", "acidification potential", "water deprivation" impact categories as well as the "non-renewable energy consumption" (nuclear + fossil fuel) inventory indicator are shown in figure 3.

It would have also been useful to show the "human toxicity" and "ecotoxicity" impact categories, but relevant data from the INRA team could not be exploited. Furthermore, in order to compare all the entire life cycles of the two tomatoes, data for logistical chains and consumption of French tomatoes calculated for the FLONUDEP Project were added to the results stopping at the INRA team's farm gate for the French tomato.

[6] *Pfister, S., Koehler, A., Hellweg, S., 2009. Assessing the environmental impacts of freshwater consumption in LCA. Environmental Science & Technology, 43 (11), 4098-4104*

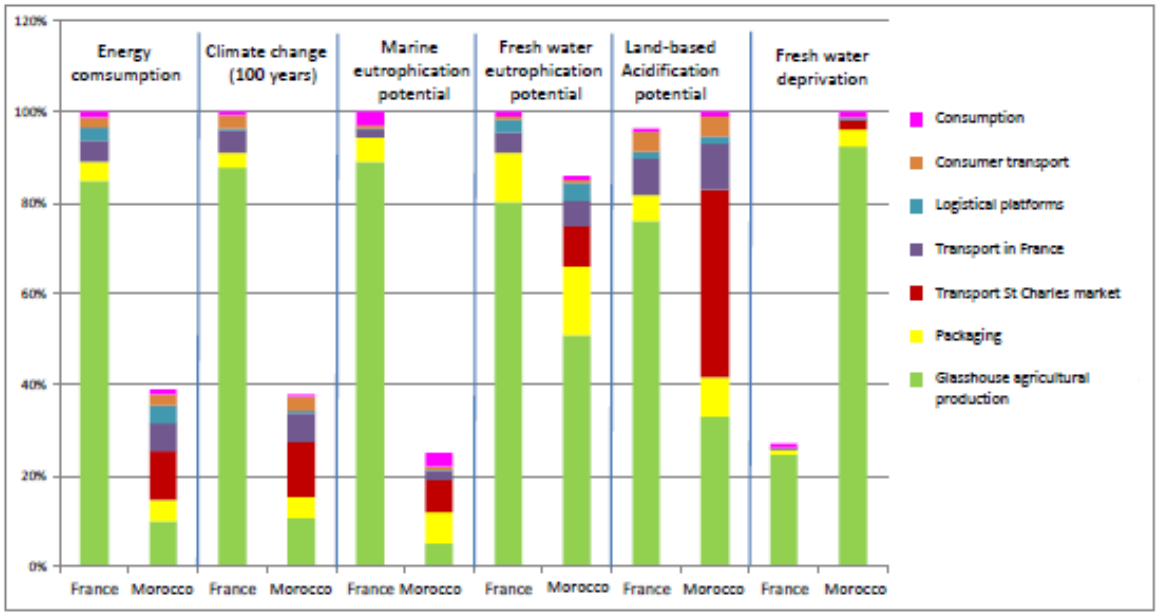


Figure 3: Environmental impacts of 1 kilogram of tomatoes produced in Morocco and in France and consumed in France

Energy consumption, climate change (100 years), eutrophication and acidification potential, as well as fresh water deprivation throughout the life cycle (from cradle-to-grave) of one kilogram of tomatoes produced in Morocco (this study) and in France (Boulard et al., 2011)[7] and consumed in France - ReCiPe (Hierarchical) method + Pfister et al's method (2009) for fresh water deprivation. The results are expressed in percentage of the highest score for each impact category.

3.1.4 Comparison of environmental impacts based on local or imported origin

Over the tomato's entire life cycle, the Moroccan system displays much lower energy consumption, climate change and marine eutrophication impacts than the French system as they amount to barely 40% for energy and climate change and just 25% for marine eutrophication (see figure 3).

For fresh water eutrophication and soil acidification, the impacts of both systems are much closer, with a lower "fresh water eutrophication" for the Moroccan system of 25% compared to the French system and a slightly higher "soil acidification". The results clearly show the contribution of the transport stage from Morocco to France tied to acidic gas emissions from fuel being burnt by trucks. Finally, as concerns the "fresh water deprivation" indicator, the ranking between the systems is very much against the Moroccan method whose impact is triple that of its French counterpart.

As a result, we cannot label one system as being better than the other for the full set of environmental indicators. Conversely, each system has its scope for progress which is explored hereafter.

3.1.5 Identifying areas for improvement in the systems

The French and Moroccan systems have very different environmental profiles.

For the French system, the agricultural stage has a major impact on all the impact categories whether this be gas-fired heating or production-related impacts and the use of fertilizers.

[7] *Boulard Th, Raeppel C, Brun R, Lecompte F, Hayer F, Carmassi G, Gaillard G. (2011). Agronomy Sust. Developm. 31:757–777*

By contrast, it is the cumulative transport stages in the Moroccan system that are the main contributors to nearly all the impacts (except fresh water deprivation and fresh water eutrophication), with an inter-country transport stage accounting for 6-17% of total impacts. These are mainly carbon dioxide gas (CO_2) and nitrous oxide (NO_x) emissions during road haulage.

The agricultural stage also makes a significant contribution ranging from 20% for marine eutrophication and 92% for fresh water deprivation. Fertigation is identified within this stage as having the greatest impact tied with fresh water consumption for irrigation, fertilizer production, nutrient emissions in the field and energy used by pumps.

The production of greenhouse materials also stands out as significant, particularly for climate change impacts and non-renewable energy consumption. Still focusing on the full life cycle of the Moroccan system, we can note the small contribution of logistical platforms (excluding transport) of 0 to 10% of impacts and household consumption (excluding transport) of between 1 and 12% according to impacts.

In conclusion, the principal weaknesses (or areas for improvement) for the out-of-season tomato systems studied are gas-fired heating in greenhouses and fertilizer use for the French system and international transport and the use of fresh water for irrigation for the Morrocan system. It is in these areas that efforts to innovate and reduce impacts must be focused. This could be done by using renewable energy sources for the French system and by comprehensive use of shipping for the Moroccan system. Scope for improvement in the use of fresh water appears more limited insofar as producers already tend to optimise their use of water. Furthermore, the use of lower quality water such as treated water from sewage treatment plants is forbidden for crops consumed raw. The problem of water in the production area of Souss in Morocco therefore remains a major issue for the future of these products.

3.1.6 Conclusions and perspectives

Our comparison is based on separate studies with different methodological choices, but with access to data sets held by the INRA team and the calculation of impacts using the same characterisation method for the Moroccan tomato which helped reduce as far as possible methodological bias when making our comparisons. In addition, apart from fresh water eutrophication and soil acidification indicators, differences between the two systems are large enough to ensure that their ranking is sufficiently robust. The most crucial problem is the lack of toxicity impacts which we were not able include in the comparison exercise as the French data sets for these categories could not be exploited. The comparison between the French and Moroccan systems still needs to be completed for these indicators.

3.2 The case of the “processing tomato” industry

The FLONUDEP Project enabled an environmental assessment to be conducted on several processed product sectors. We limited our study to the tomato paste industry and tomato sauces produced and marketed in France and the tomato paste industry in Turkey and tomato paste exports to France. This enabled critical aspects to be identified in the various industries, knowing full well that the findings focus on a limited number of companies and do not necessarily reflect results derived from comprehensive studies. They do however indicate strong trends. The scope of the study in France and in Turkey is shown in figure 4 below.

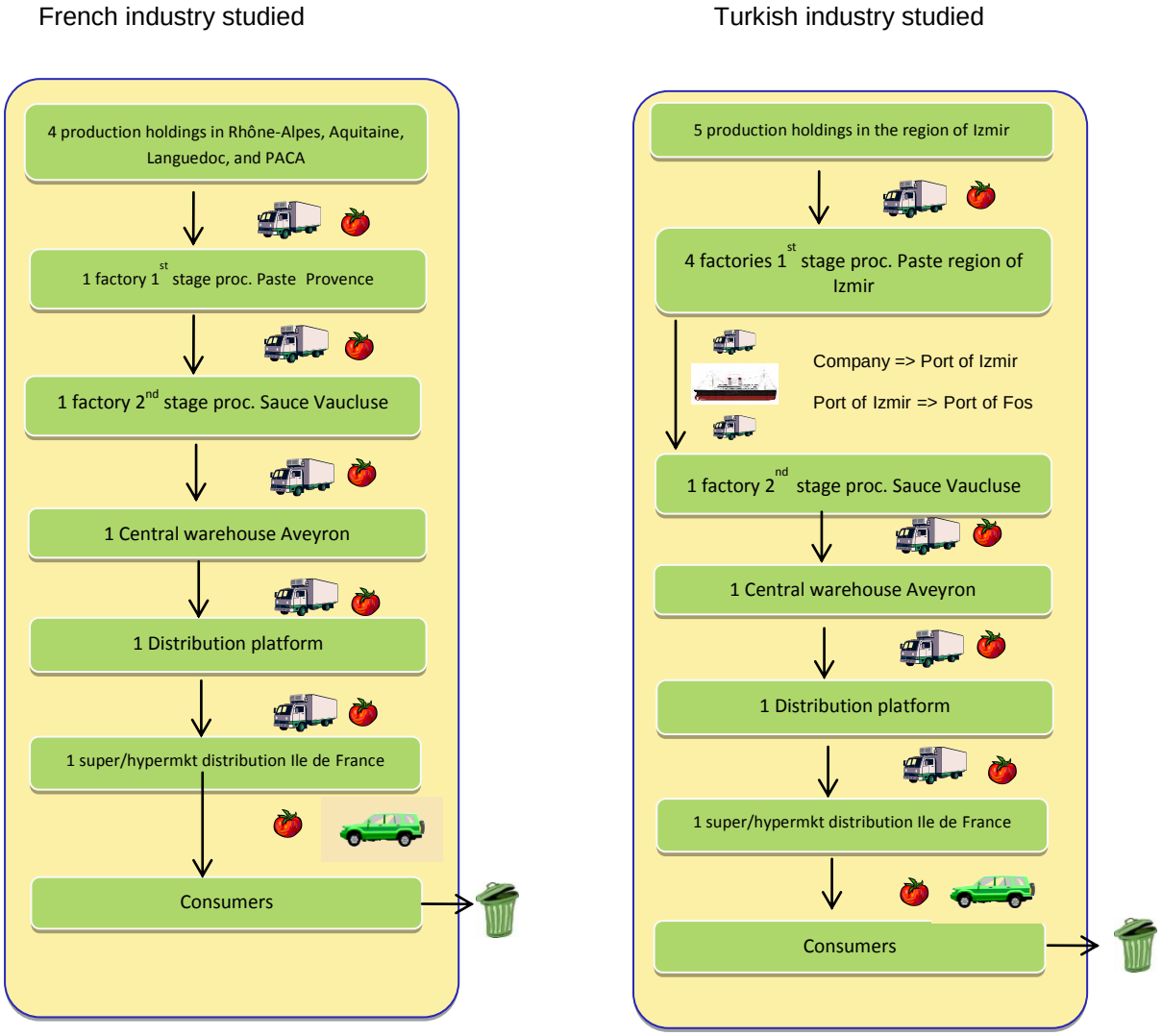


Figure 4: Scope of study in France and in Turkey

3.2.1 Regarding farms and processing tomatoes

Among the technical operations in both France and Turkey (fertilising, preparing the soil, planting, protection, harvesting and post-harvesting work), the activity that causes by far the biggest impact is fertilising for nearly all the impact categories considered (global warming - F = 62.7%, T = 61%, acidification - F = 41%, T = 86% and eutrophication - F = 95%, T = 93%). The second highest scoring activity is soil preparation and harvesting (51% of acidification, 36% of human toxicity risks and 30% of GHG in France). In contrast, as concerns human toxicity, plant protection treatments also play a fairly significant role in France.

Still in France, differences can be seen between farming practices in the South East and the South West. Due to the different soil and climate conditions, there is greater use of fertilizers in the South East compared to the South West whereas the reverse is true for pesticides. As a result, acidification and eutrophication impacts are respectively 1.5 and 1.4 times higher than production in the South East although GHG and human toxicity effects are similar.

If we look at other analyses conducted in other countries on similar products (field tomatoes) and with the same study perimeter, we can see that overall orders of magnitude per impact category are similar, which gives our study a certain degree of robustness. By comparing the findings, we can see that although eutrophication is higher in Turkish production systems, greenhouse gases while acidification problems are greater in Spain (Martinez-Blanco, J. et al., 2011)[8]. French farms sit in the middle in all impact categories.

Impact category	Unit	Tomato France	Tomato Turkey	Tomato Spain
GHG	kg CO_2 eq	0.03424099	0.07951771	0.150
Acidification	kg SO_2 eq	0.00058862	0.00049713	0.000888
Eutrophication	kg PO_4 eq	0.00030962	0.00037501	0.000234

Table 1: Comparison of environmental impacts in France, Turkey and Spain

3.2.2 At the factory stage

For the companies, the key critical point is packaging. In France, packaging accounts for 93-95% of GHG emitted by companies, 25-99% of human toxicity and 27-99% of eutrophication depending on the types of packaging. By comparing plastic bins and metal drums, which are the most commonly used forms of packaging for tomatoes destined for 2nd stage processing factories, the metal drum generates 1.5 times more GHG per kg of paste, 700 times more human toxicity risk and 8 times more eutrophication than the plastic bin.

By looking exclusively at paste production operations (excluding packaging), electricity is almost entirely responsible for all impact categories, with the exception of eutrophication. Electrical energy is also a significant contributor to impacts generated by the production of sauces (41% of human toxicity, 26% of acidification and 19% of eutrophication). That said, it is nevertheless the production of steam which has the greatest impact (74% of GHG, 70% of acidification and 54% of human toxicity). As concerns production itself, this mainly features in eutrophication, with 66% of the factory total.

In Turkey, results confirm packaging as the critical point, although there is a significant difference depending on the form of packaging. The tin can clearly has the greatest impact (72-91% of GHG, 94-97% of eutrophication and 81-94% of human toxicity, depending on the factory). The glass jar appears much more ecological at this stage as it generates 15-times less acidification impact, 7-times less eutrophication impact, nearly 4-times less GHG and nearly 3-times less toxicity (the packaging end of life is not considered at this point but at the consumer stage). Finally, the metal drum has genuine advantages in terms of GHG (18% of factory emissions) and eutrophication (18% of factory emissions), but it is a problem for human toxicity (94% of total factory impact).

Aside from packaging, the other big contributor is the energy used to make the product itself. Indeed, the use of oil or gas causes 24% of GHG for paste in a glass jar, 26% for paste in a tin and 81% for the paste in a drum.

The factory is part of a whole and consequently, of the 4 factories studied in Turkey, the one with the biggest overall impact actually displays the lowest impacts in terms of transporting tomatoes from the field to the factory.

[8] *Martínez-Blanco J, Muñoz P, Antón A, Rieradevall J. (2011). Journal of Cleaner Production, 19: 985e997*

3.2.3 At the logistics stage

Logistics are frequently called into question in a product's environmental impact. This study considers transport-related emissions throughout the processing tomato industry and reveals several critical points. In France, the journey from the 2nd stage processing factory to the supermarkets has the greatest impact (92% of GHG, 82% of human toxicity and 89% of eutrophication for logistics as a whole). The distances covered are very long and highlight the need to review logistical chains. In Turkey, although you might instinctively think that the longer the journey between the production site and the consumer point of sale, the greater the impact, findings from the study actually show that it is the means of transport travelling this distance that plays a key role rather than than the distance itself. Let us take, for example, tomato paste produced in Turkey and then transported to France by ship. The environmental impact is mainly generated by truck or tractor transport from the farm to the first-stage processing factory, then the journey from the factory to the port of arrival in France (this journey includes TIR transport from the factory to the Port of Izmir in Turkey as well as the journey by ship to the Port of Fos sur Mer in France). This applies to 3 of the impact categories chosen (eutrophication, GHG and human toxicity) which are respectively 3-times, more than 4-times and 11-times greater at the pre-factory stage than at the post-factory stage. If the final journey by truck is added from the French port to the supermarket, the pre-factory stage in Turkey is still the critical point for all criteria, except for GHG emissions which subsequently increase for post-factory transport. These main trends are confirmed for Turkey (Karakaya, Ozilgen, 2011)[9].

3.2.4 At the consumer stage

Consuming a product requires a series of preliminary actions (such as the journey to purchase the product, storing it in the house and preparing it) as well as actions after consumption (such as recycling and waste processing). As part of the results from the FLONUDEP Project, based on a survey of 800 people of 20-65 years old, we can observe that the purchasing stage plays a key role. Indeed, most consumers buy from super/hypermarkets and use their cars which generates considerable pollution, particularly in relation to global warming. For fresh tomatoes, for example, purchases contribute to about 90% of acidification, human toxicity and GHG and more than half of eutrophication stemming from consumer activities. For processed tomatoes, the impact of preparation (cooking) and the end of life of the packaging (tin can) is also significant.

The main purpose of a LCA is to be able to compare the environmental impact of one product with that of another and to have the arguments for informed choices. For this reason, it has been decided to compare the environmental impacts of two methods of preparing tomato sauce at home. One uses fresh tomatoes and the other used processed tomatoes from a tin can. Indeed, the consumer chooses between the products having the same function. At home, 2kg of fresh tomatoes and 30 minutes cooking time on an electric hob (the most commonly-used way of cooking according to our surveys) are required to make 1kg of sauce. The results show that in terms of global warming and acidification, both types of sauce have a similar impact. By contrast, for the two other impact categories taken into consideration, the results are mixed. Eutrophication is 1.5-times higher for the "homemade" sauce whereas human toxicity potential is 10-times higher for the "industrial" sauce due to the manufacture of the tin can which comes with it. In the first case, the use of water is the issue whereas in the second case it is the tin can.

[9] *Karakaya A, Özilgen M (2011). Energy 36 (2011) 5101e5110*

3.2.5 Considering the food chain as a whole

The FLONUDEP study helps highlight major critical points of supply chains and the use of industrial tomato products on the basis of two case studies. The first involves canned tomato sauce sold in France made from paste manufactured in France and packaged in drums while the second is made from paste packaged in drums from Turkey.

Overall, the 1kg tin of sauce purchased, used by the consumer and then recycled slightly favours French industry for GHG and human toxicity. The Turkish and French industries are identical in terms of eutrophication.

Regardless of the supply chain, the highly critical points are clearly the companies, particularly the 2nd stage processing factories. Indeed, it is at this stage that most of the emissions (¾) are generated, especially for GHG and eutrophication with the tin can and the energy used to produce steam (mostly natural gas) being the main causes.

As regards human toxicity risks, the 1st stage processing company is also the critical point because the manufacturing of the containers (metal drums) is affected to them. The consumer stage also displays a significant proportion of human toxicity risks with almost 20% of the total chain. This is due to the consumer stage being allocated the task of recycling the tin can. Finally, more than 10% of total eutrophication in both France and Turkey is generated at the farming stage due to the use of fertilizers.

	Farm	Transport	1st stage proc. plant	Logistics	2nd stage proc. plant	Logistics to the smkts	Smkt	Consumer	TOTAL
GHG	2.7	0.8	12.3	0.3	73.4	4.0	0.7	5.9	100
Human toxicity	0.9	1.1	46.7	0.1	32.0	0.8	1.4	17.0	100
Fresh water eutrophication	12.6	0.8	2.7	0.3	77.5	1.6	0.2	4.3	100

Table 2: Associated impacts of the French tomato sauce chain using Turkish paste (for 1kg of sauce, in %)

	Farm	Transport	1st stage proc. plant	Logistics	2nd stage proc. plant	Logistics to the smkts	Smkt	Consumer	TOTAL
GHG	1.9	0.2	2.5	0.1	83.3	4.5	0.8	6.7	100
Human toxicity	1.3	0.1	41.2	0.1	35.9	0.9	1.5	19.0	100
Fresh water eutrophication	12.2	0.1	4.1	0.00	77.5	1.6	0.2	4.3	100

Table 3: Associated impacts of the French tomato sauce chain using French paste (for 1kg of sauce, in %)

Issuing a final opinion is delicate as in light of the Turkish study, we can see that the same company can perform more effectively in one of the activities (transport of paste, for example) than in another (manufacturing the paste). This leads us to say that despite some strong trends, each case is specific. There are very few studies that give consideration to the whole production, processing and distribution system. FLONUDEP can therefore be considered as a pioneering study in France.

4 The social and economic impact of the industries

4.1 SLCA: a recent methodology in the making

Social life cycle assessment (SLCA) is a tool to estimate social (and economic) impacts, making it possible to compare production sectors. The methodology is not yet stable but recommendations from work by UNEP-SETAC[10] have helped propose a methodological framework which nevertheless acknowledges that numerous questions still need to be addressed. The literature on the subject is recent (first articles published less than ten years ago) and is beginning to sketch out the main approaches[11].

Today, two of them seem to conflict with each other:

- the first, *SLCA attributes*, is in keeping with work on corporate social responsibility (CSR). It positions itself solely in the sphere of internal corporate performance which makes it impossible to really measure social impacts. It provides information on companies' "social" actions and enables social criteria to be monitored over time.
- the second, *pathways analysis* researches significant relationships between factors and impacts. It seeks to measure the transformation of social conditions and the effect on the population's well-being.

We propose a third avenue in that of the SLCA of capacities.

4.2 The rationale of our approach

What SLCA of attributes calls *social* derives from a set of variables that economists rank in the spheres of *human capital* (health, education, work, skills) and *social capital* (cohesion, diversity, equality, inclusion, etc.).

As part of measuring performance, there is no need to identify the causes and models that explain the results. Distinguishing between flows or assets with different functions is also of no particular benefit.

Although sustainable development provides a background, the lack of a theoretical benchmark on the social role also explains the confusion in terminology.

From our standpoint, *there is a need to understand the development of SLCA methods in line with the contributions of the social sciences*, not as a simple tool stemming from the need for commercial legibility of firms present in the markets, but rather as an instrument to measure variations in stakeholder positions in a development context. This instrument can be applied to all stakeholders. This is why the overall framework to our approach will have a multi-capital sustainable development model perspective to distinguish social and human dimensions as well as economic (technical and financial), natural and institutional dimensions too.

[10] *Guidelines for social life cycle assessment of products, United Nations Environment Programme, 2009 (www.unep.fr)*
[11] *International seminar in Social Life Cycle Assessment (Montreal, 6 and 7 May 2013) (www.ciraig.org)*

Our methodological proposal makes it possible to identify corporate impacts rather than the performance and uses both internal and external information. In addition, the nature of the impact results from a systematic investigative approach on *variations in stakeholder capacities* in connection with the development of a production sector.

Context is important from this standpoint and the advantage of this approach is that it reconciles both the demands of identification and the estimation of multi-stakeholder impacts as part of a multi-capital development model (MCM).

4.3 General protocol for an SLCA of capacities

The aim of the social life cycle assessment of capacities is to link an analysis of the industry with a MCM approach by selecting just five prospective categories of capital (excluding natural capital which is studied elsewhere). The purpose is to measure variations in the capacities of the various industry stakeholders that stem from the corporate social practices.

These capacities are likely to grow or decline over time and these variations affect different capital stocks. As we have already emphasised, *the difference between performance and impact is the difference between an internal measure and an overlapping internal-external measure.*

Providing a training course, for example, to employees is a CSR performance indicator. But, for us, it is simply a *condition likely to produce an effect on capacities*. There is no guarantee that providing a training course means that it will be followed. Furthermore, the fact that an employee follows this training course does not mean that it will effectively increase their knowledge (the problem concerning the effectiveness of education). If this was the case, their improved knowledge would only be the cause of a *potential effect of capacity*, without being certain that it was an *effective or real increased* capacity; the latter would be derived from the stakeholder transforming their knowledge into a skill. The real Effect of Capacity procured from an employee following a training course will be measured in their increased productivity, or by their increased ability to adapt, etc. To make this possible, specific technical conditions must be met such as making equipment available or modifying the employee's job. However, to establish the link between increased knowledge and increased productivity, or greater versatility, ad hoc studies must be conducted. This is what is referred to in SCLA as "Pathways".

According to this example, it seems to us that the main benefit SCLA has on capacities is to distinguish and estimate different situations including, *the training offered*, *the training followed*, *the capacity building training* and *the significance of the capacity acquired*. The second benefit is to study and estimate the variations concerning potential effects of capacity for all capital categories and not just human capital.

The different stages of the SCLA on capacities are as follows:

1-identification of capital categories and sub-categories;

2-identification of the potential effects of capacity;

3-identification of indictors to measure the potential effects of capacity;

4-identification and collection of information internally (127 questions);

5-identification and collection of external information (external data from the views of unions and local communities regarding local, national, international regulations and industry standards, etc. This external information set is generally collected by an expert);

6-assessing the variations in potential effects of capacity (the internal survey is compared with external data and we therefore assign positive or negative values to each indicator based on the judgement made about the way this variable changes).

The ultimate objective would be to move from the potential effects of capacity to real effects.

4.4 Applying the SLCA of capacities

A-Our scope was firstly to conduct *a social life cycle analysis of the Moroccan fresh tomato destined for export to France*. In this context, our methodology, which is still being assembled, has not been applied systematically. Furthermore, conditions for access to information proved to be difficult.

The Moroccan "export tomato" sector comprises the following life cycles which were included in the scope of our study:

- production of tomato plants (nursery)
- greenhouse agricultural production (farm)
- packing (packing stations)
- marketing (marketing office)
- transport "from the packing stations in Agadir to Perpignan"

The nature of data collected led us to merge the packing, marketing and transport stages. The surveys were conducted in the region of Souss with stakeholders surveyed representing the various stakeholder categories throughout the chain:

1- “commercial nursery” plant producers

2-vertical integration “ensuring production, packing, marketing and transport”

3-producer-provider company “ensuring packing and marketing”

4- producers-providers “ensuring farm production for the company referred to above”

5-cooperative “ensuring packing and marketing”

6-farmer cooperatives “ensuring production for the cooperative referred to above”

The study sample covers 45% of national tomato exports, 80% of which are destined for the French market.

The collection of data required to conduct the study was done using five investigation methods:

1-the collection of documentation on-site

2-discussion with researchers (Hassan II Institute, Agadir)

3-a stakeholder questionnaire,

4-semi-structured interviews with stakeholders,

5-direct observations on how operations are run.

Data analysis and processing was undertaken following the "social life cycle assessment of capacities" methodology. Our results have been provided in the form of quantified indicators concerning:

1- economic effects: we estimated the *direct added value* generated by the various stages studied in the life cycle of the Moroccan export tomato. We estimated the proportion of this added value in the sale price as well as that for imports of production components. The estimation of direct and secondary added value may be useful in a future study;

2- social effects: the main estimated social effects were *employment* and *social expenditure;*

3- human effects: here, only *working conditions* were addressed;

4- institutional effects: these are *employee relationships* (existence of work contracts, unions, etc.);

5- environmental effects: only *the water resource* was studied by estimating the quantities, financial value and origin of the water used depending on the life cycle stage studied. It would be useful to estimate the real economic value of this natural resource which is crucial to the operation of the industry.

B- *The social life cycle assessment of the Turkish processing tomato destined for export to France.*

We have applied the proposed method in a systematic way for this study as well as the following one (the French processing tomato industry).

The following representation (table 4) combines the identified variations of capacities by adding together the different levels by stakeholders and by sub-categories. (M. Garrabé and H. Yildirim[12]). We have therefore made aggregations of both the positive variations and the negative variations, firstly by level (for example + and ++) then between levels (for example, 1+ and 2+ = 3+).

This table shows, for example, that:

- for human capital, the industry provides good levels of pay, particularly processing and logistics companies (high levels of + in dark green in the "C.Trav" column). There is also ease of access to health care in the processing and logistics companies ("Health" column). Conversely, the training aspect is very neglected by certain processing companies (negative figures in pink and red in the "Educ" column);
- for technical capital, we can highlight significant investment in infrastructure (roads, buildings) which favour the companies;
- for financial capital, we can see that the farmers benefit from large subsidies (Sub column) and that companies have a good level of equity, providing reasonable security for financial capital;
- conversely, social capital is less positive where there is no union and little social dialogue is possible (negative figures in pink).

[12] *Garrabé M and Yildirim H (2012) SCLA of the capacities of the Turkish processing tomato industry exported to France report ANR-FLONUDEP.N°5*

	Human capital	Technical capital	Financial capital	Social capital	Institutional capital

	Capital Humain					Capital Technique					Capital Financier						Capital Social					Capital Institutionnel				
	Educ	C.trav	Santé	Sécu	Pari	Entr	Infra	Info	Marc	Adm	Sbv	CaPr	Epar	Salai	R.pu	Créd	Just	Part	Conf	Int.C	RéS	R.Pr	R.Su	R.Ré	R.Co	R.Ar
P1	2+	4+	2+	0	0	4+	2+	0	0	0	6+	2+	0	0	1+	0	1+	0	2+	2+	2+	0	1+	0	2+	0
P2	2+	4+	4+	2+	0	4+	4+	0	0	0	6+	0	0	0	1+	0	1+	0	2+	2+	2+	2+	0	0	2+	0
P3	2+	4+	2+	0	0	0	2+	0	0	0	6+	0	0	0	1+	0	0	0	0	2+	2+	2+	0	0	0	0
P4	0	4+	2+	0	0	0	2+	0	0	0	6+	0	0	0	1+	0	1+	0	2+	0	2+	2+	1+	0	2+	0
P5	0	4+	2+	0	0	2+	2+	0	0	0	6+	2+	0	0	1+	0	0	0	2+	2+	2+	0	1+	0	2+	0
P6	0	4+	2+	0	0	2+	2+	0	0	0	6+	2+	0	0	1+	0	1+	0	0	2+	2+	2+	1+	0	2+	0
P7	0	4+	2+	0	0	2+	2+	0	0	0	6+	2+	0	0	1+	0	1+	0	2+	2+	2+	2+	1+	0	0	0
P8	0	4+	2+	2+	0	6+	2+	0	0	0	6+	0	0	0	1+	0	0	0	2+	2+	2+	2+	1+	0	2+	0
P9	0	4+	2+	2+	0	6+	2+	2+	0	0	6+	0	0	0	1+	0	1+	0	2+	2+	2+	2+	1+	0	2+	0
P10	0	4+	2+	0	0	2+	2+	0	0	0	6+	0	0	0	1+	0	1+	0	2+	2+	2+	0	1+	0	0	0
T1	5+	9+	7+	3+	5+	10+	5+	6+	6+	3+	3+	6+	4+	2+	2+	0	7+	7+	5+	4+	6+	9+	6+	4+	4+	3+
T2	3+	8+ 3-	5+	3+	4+	5+	7+	4+	5+	2+	3+	3+	3+	1+	2+	3+	2+ 2-	2+ 2-	2+ 1-	2+	2- 3+	2-	6+	4+	2+	3+
T3	4+	12+	6+	3+	3+	7+	5+	1+	6+	2+	5+	6+	2+	3+	2+	4+	5+	6+	4+	3+	4+	6+	4+	3+	2+	3+
T4	1+ 4-	5+ 2-	4+	5+	3+	9+	4+	1+	2+	1+	3+	6+	6+	1+	2+	4+	4+	1+ 2-	4+	2+	2+	4+	3+	1+	2+	2+
T5	3+ 2-	5+	4+	3+	6+	4+	6+	1+	5+	2+	3+	4+	2+	1+	2+	0	6+	3+ 2-	4+	1+	4+	4+	3+	1+	2+	3+
L1	5+	10+	7+	5+	7+	10+	8+	8+	7+	2+	3+	6+	2+	2+	2+	3+	7+	6+	5+	4+	5+	7+	4+	2+	2+	4+
L2	5+	10+	7+	3+	7+	10+	8+	4+	0	2+	4+	6+	6+	0	2+	0	7+	3+	4+	1+	3+	5+	4+	2+	2+	4+
L3	0	7+	3+	2+	3+	4+	2+	2+	3+	2+	2+	4+	6+	0	2+	0	5+	2+	4+	1+	3+	3+	2+	0	2+	3+

Turquie

Table 4: Aggregation of positive and negative variations in the capacities identified in the Turkish industry

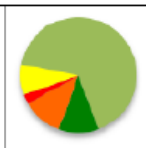
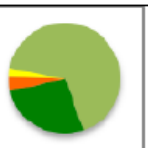
Abbreviations in Table 4

P = producteur ; **T**= entreprise de transformation ; **L**=entreprise de logistique
P = producer; **T** = processing company; **L** = logistics company

Human capital	Technical capital	Financial capital	Social capital	Institutional capital
Éduc : Éducation ***Education***	**Entr** : Entreprises ***Companies***	**Sbv** : Subvention ***Grant***	**Just** : Justice/Équité ***Justice/fairness***	**R.Pr** : Règles de protection ***Rules of protectiont***
C. trav : Conditions de travail ***Work conditions***	**Infra** : Infrastructure ***Infrastructure***	**CaPr** : Capitaux propres ***Equity***	**Part** : Participation ***Participation***	**R.Su** : Règles de surveillance ***Rules of monitoring***
Santé : Santé ***Health***	**Info** : Informations ***Information***	**Epar** : Épargne ***Savings***	**Conf** : Confiance ***Trust***	**R.Ré** : Règles de régulation ***Rules of regulation***
Sécu : Sécurité ***Security***	**Marc** : Marchés ***Markets***	**Salai** : Salaires ***Salaries***	**Int.C** : Intégration/Culture ***Integration/Culture***	**R.Co** : Règles de couverture ***Rules of coverage***
Pari : Parité ***Parity***	**Adm** : Administration d'entreprise ***Administration business***	**R.pu** : Ressources publiques ***Public resources***	**RéS** : Réseaux sociaux ***Social networks***	**R.Ar** : Règles d'arbitrage ***Rules arbitration***
		Créd : Crédit ***Credit***		

C- The social life cycle assessment of the processing tomato in France.

For the SCLA of the French processing tomato industry, a different form of presenting the results was tested[13].

VCBC *	Prod. Org. .	Producer	Processor 1	Processor 2
Human capital				
Technical capital				
Financial capital				
Social capital				
Institutional capital				

*Variation in capacity by company

Key:

	Percentage of **weak growth** of capacity by capital and by stakeholder.
	Percentage of **strong growth** of capacity by capital and by stakeholder.
	Percentage de **slight decline** of capacity by capital and by stakeholder.
	Percentage de **sharp decline** of capacity by capital and by stakeholder.
	Percentage of **zero change** of capacity by capital and by stakeholder.

Table 5: Variations of Capacities by capital type for the French industry

Generally speaking, in this type of representation, the more the pie-charts are green, the more satisfactory the situation is. By contrast, the more they are orange or red, the more there is cause for concern. As such, we can see that the financial capital and occasionally, the human capital are jeopardised. Technical, social, and institutional capital are, on the whole, satisfactory for our sample.

As concerns producer organisations, apart from financial difficulties, we can highlight the lack of an occupational risk and illness prevention system in human capital. On the other hand, the possibilities for experimentation and a healthy number of spaces for dialogue make the technical and social capital positive.

[13] *Garrabé M, Pédemay A (2012). SCLA of the capacities of the French tomato industry. Report N°4, ANR FLONUDEP Project.*

The producers surveyed do not benefit from supplementary insurance (human capital) or a collective agreement (institutional capital), but they do enjoy housing support and have no problem employing older people (social capital). We can highlight their economic fragility because of their continued reliance on subsidies.

Finally, for processing companies, we can highlight a significant financial deficit which weakens their position, but they have good legal assistance (institutional capital).

D- Comparison between processing tomato production in the French and Turkish industries.

The two studies undertaken as part of the Flonudep Project enabled the SLCA of capacities to be applied to the processing tomato industry in both France and Turkey.

We have more surveys for the Turkish industry than for the French. We therefore selected four of the most representative stakeholders or stakeholder groups so as to dispose of a set of information comparable with the French industry.

In order to make a comparison between the results obtained for the different industries, it is important, that items are standardised and that there is an identical number of observations. This issue can clash with contextualisation requirements that we have previously identified. The aggregation of results is only illustrative because nothing indicates that the values for levels of growth or decline are equivalent. For the moment, the question of the value of levels remains unanswered.

Tables 6 and 7 are the result of protocols applied to the Turkish and French industries and provide a summary of the previous tables. It is, in principle, possible to aggregate the *gains and losses of capacity* for all the operators throughout the industry, although caution is needed for the moment. The results are positive in both countries for all types of capital, but there are significant differences. Although the French industry is financially fragile, human, technical and social capital are in very good shape. In the Turkish industry, institutional and social capital may be lacking but financial and human capital seems to be relatively satisfactory.

Human capital	Technical capital	Financial capital	Social capital	Institutional capital
97	**109**	**19**	**80**	**61**

Table 6: Aggregation of capacities in the French processing tomato industry

Human capital	Technical capital	Financial capital	Social capital	Institutional capital
51	**49**	**50**	**41**	**32**

Table 7: Aggregation of capacities in the Turkish processing tomato industry

We must underline caution concerning comments about these results. *A weak variation of capacity can have greater relative effects than a strong variation if the capacity level is weaker from the outset.*

5 Nutritional assessment

Checking that products do not lose their nutritional qualities is a prerequisite for assessing an industry, especially when it comes to products from various origins in terms of soil and weather which are likely to alter while being transported, or to be processed.

Taking nutritional characteristics into account can help arbitrate between two equivalent practices from an environmental and social standpoint.

Here, we present a nutrient profiling system that we have adapted to study fruits and vegetables as well as the methodology used to apply it to the tomato industry.

5.1 Methodology

To better describe the tomato's overall nutritional quality it was decided to use the SAIN-LIM profiling system.

5.1.1 Presentation of the SAIN-LIM tool

The SAIN-LIM nutrient profiling system was proposed by Anses (ex-AFSSA) for the purposes of applying the European regulation on nutrition and health claims (Regulation EC 1924/2006). This system is based on the idea that each food presents nutritional qualities and drawbacks (and not on the idea that there are good and bad foods).

This profiling is based on two separate scores:

- **the SAIN score** which represents a summary of the product's "positive" aspects. This is a score for nutrient density calculated from 5 nutrients with a positive role in dietary balance and on public health in general. These are proteins, fibre, vitamin C, calcium and iron expressed in 100 kcal of the food (added nutrients are not considered in the calculation).
- **the LIM score** represents the product's "negative" aspects. It is the average percentage of maximum recommended values of 3 nutrients whose intakes must be limited as part of a balanced diet. These are sodium, added sugars and saturated fatty acids in 100 g of the food.

Each score is expressed as a calculated and significant unit. In other words, the score calculated is not an arbitrary number as in all other existing profiling systems.

5.1.2 Adapting the methodology to fruits and vegetables

In the conclusion of the Anses Report on the SAIN-LIM System, the experts offered to adapt these indicators to the food category studied, "Likewise, the optional nutrient scheme can be adapted to the objective set and enhance the performance of the profiling tool. The development of optional nutrient schemes could help evolve this profiling tool into a category-based scheme*."*

In this context, the SAIN indicator was altered and adapted with nutrients symbolising the best nutritional characteristics of fruits and vegetables.

To do this, the contribution (in %) of total intake for each of the nutrients in fruits and vegetables category had to be calculated for the French population. This was done using data from the INCA1 study (1999), the underlying principle being that the highest percentages correspond to nutrients representing the best nutritional benefits specific to each category.

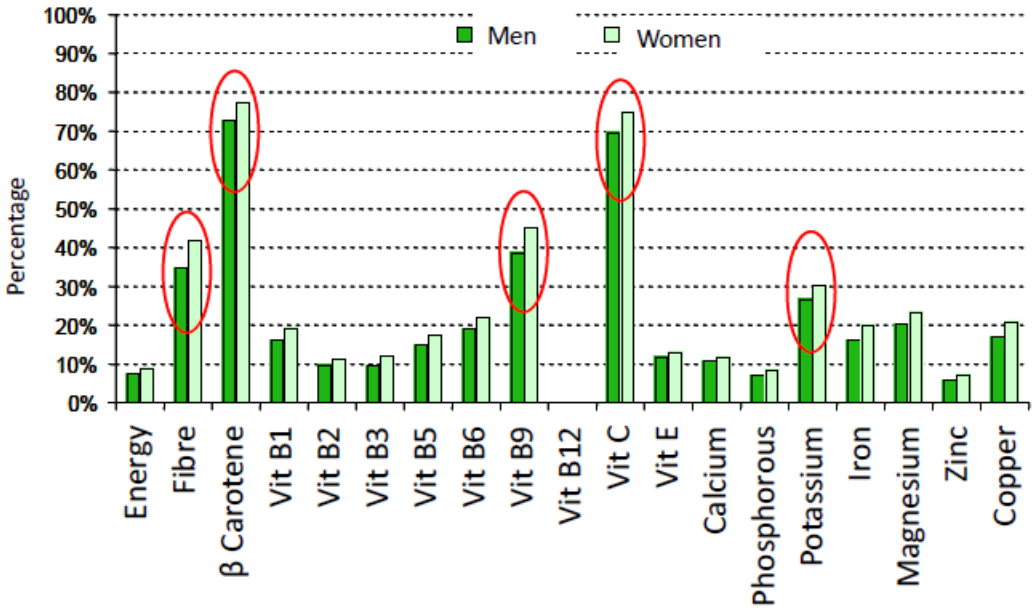


Figure 5: Percentage contribution of total nutrient intakes for the fruits and vegetables category

The percentages represent the contribution of the category corresponding to total intakes of nutrient N in the overall French diet. It can be seen that the fruits and vegetables category provides, for example, more than 70% of total intake in beta-carotene and vitamin C.

This tells us that the five nutrients that best represent the nutritional benefits of the fruits and vegetables category are fibre, beta-carotene, vitamin B9, vitamin C and potassium.

The indicator used to express the overall nutritional quality of fruits and vegetables is called $SAIN_{FEL}$ and is calculated as follows:

$$SAIN_{FEL} = \frac{\frac{Beta\text{-}carotene\ Qty}{4200} + \frac{Fibre\ Qty}{30} + \frac{VitC\ Qty}{110} + \frac{VitB9\ Qty}{315} + \frac{Potassium\ Qty}{3100}}{\frac{5}{100}}$$

The quantified data appearing as a denominator for each of the quantities of the 5 nutrients are recommended dietary allowances (RDA's) for each nutrient considered.

The quantities (or values) are expressed in:

- grams for fibre
- milligrams for vitamin C and potassium
- micrograms for beta-carotene and vitamin B9

The result is expressed as a dimensionless number representing a 100 kcal intake for the product consumed. This makes it possible to overcome the differences in dry matter between products.

If we use the values in the CIQUAL composition table for fresh tomato products and tomato paste, the $SAIN_{FEL}$ values are 63.8 and 21.2 respectively.

Finally, it was decided to use the nutrient content and $SAIN_{FEL}$ indicator for impact calculations.

5.1.3 Example of results

The following diagram represents the change in $SAIN_{FEL}$ during the “Cold Break” manufacturing process for tomato paste which begins with an initial value of 148 and drops to 120 after a few minutes at around 70°C to reach 109 at the end of the process after sterilisation.

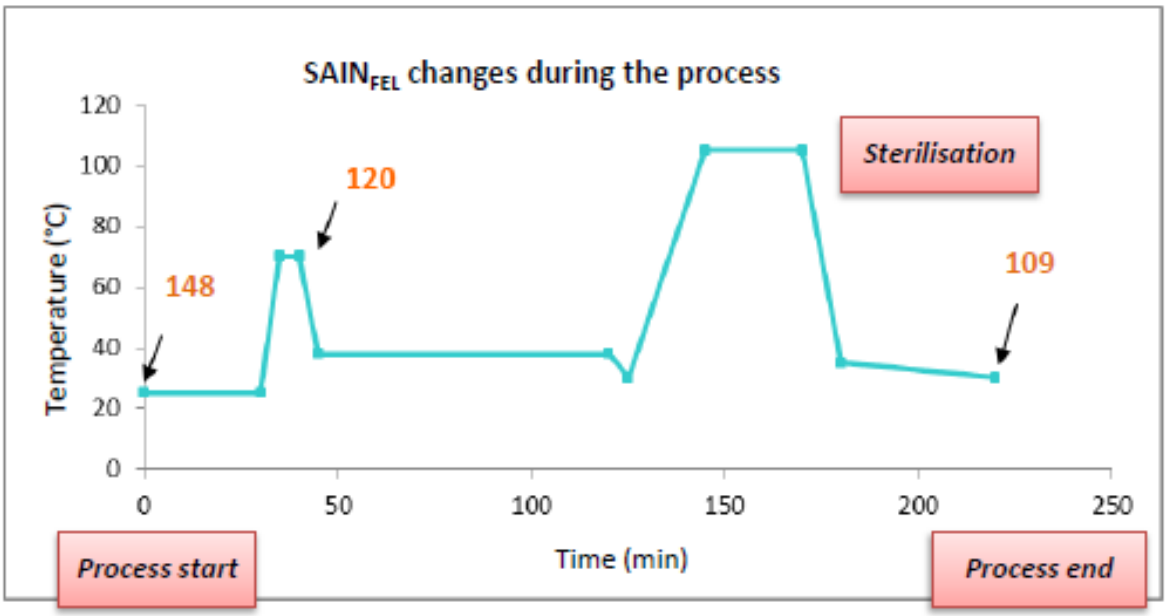


Figure 6: Example of $SAIN_{FEL}$ change during the manufacturing process

The other option is to represent each of the 5 nutrients entering into the $SAIN_{FEL}$ calculation.

The representation below helps visualise, for example, that vitamin C is strongly affected by the process (2½-fold reduction).

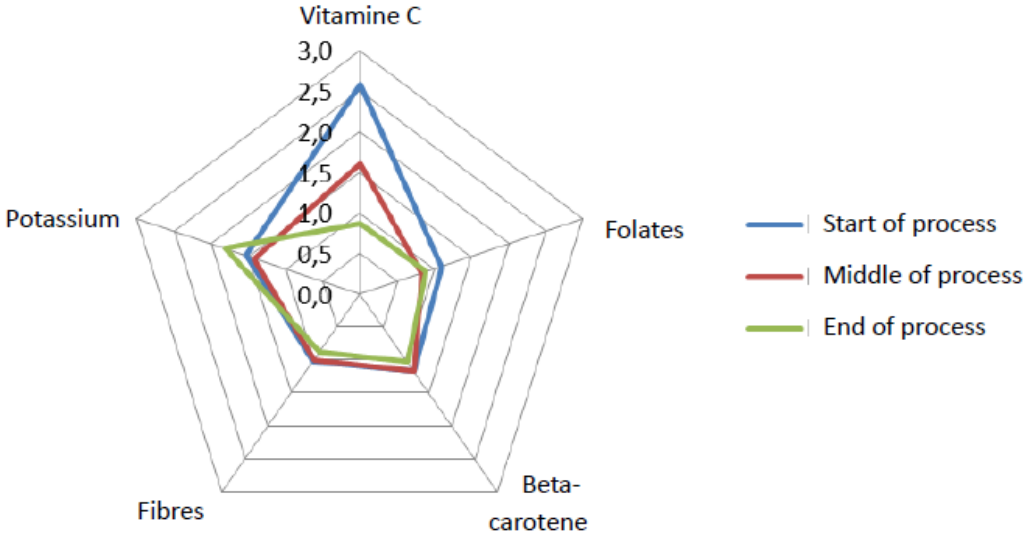


Figure 7: Example of a representation depicting the changes in 5 nutrients forming the $SAIN_{FEL}$ during a production process

5.2 Application: assessing the fresh and processed tomato industry

5.2.1 Generalities: parameters likely to affect the nutritional quality of the tomato

Several parameters linked to the physiology of fruits and vegetables (F&V) and the different environments they have experienced from their production to their consumption influence their nutritional value. The quality of the product first develops in the field, based on production conditions. Although several articles address the link between growing conditions and fruit quality, most of them focus on the accumulation of macronutrients in fruits (water content, organic acids, sugars, etc.). There are even models that help predict the accumulation of dry matter and some macronutrients depending on growing conditions. By contrast, the literature on aspects used to calculate $SAIN_{FEL}$ is less common and in any case, there is currently no model, even an empirical one, that enables the knowledge to be pulled together to identify the agronomic drivers that regulate the content of these products. Recommendations for fertilizer applications, water intake, adjusting fruit load and number of plants per hectare, etc. are highly dependent on the types of F&V (roots, foliage, stalk, perennial plants, tree) and growing conditions which can vary greatly (open field, glasshouse, irrigation, farming in cold or hot regions, etc.). The optimal climate and soil conditions have to be adapted to each type of product.

Following harvest, conditions can vary greatly from one fruit to another, although general recommendations can nevertheless be given for critical parameters having a potential effect on safeguarding nutrient density.

5.2.2 The case of fresh market tomato

If tomatoes are stored at 20°C, they will ripen normally (tomatoes are one of the fruits that ripen after being picked). In these conditions, the tomatoes are going to build up carotenes and vitamins which will have a rather positive effect on the SAIN score.

If they are stored at 30°C, the ripening process is very fast and even a short period at this temperature can trigger the ripening phenomenon and be very detrimental to future storage at a lower temperature.

If stored at 12°C, ripening is simply slowed down (which enables it to be stored for longer) but the joint increase in carotene and vitamin content is also reduced. On the other hand, when they are removed from 12°C and kept at ambient temperature, the ripening process resumes and the tomatoes regain a large part of the nutritional value (and even a most of their flavour). This is, in theory, the ideal temperature to keep tomatoes.

By contrast, if stored at 4°C, the tomatoes are below their cold tolerance threshold (around 7/8°C) which triggers physiological malfunctions called “chilling injury”. As a result, the carotenoid combination is altered as the fruits use up their vitamin C reserves when reacting to the stress induced. The stress is even greater if the ripening process has been triggered before storage (i.e. when the tomatoes turn orange). In addition, when removed from cold storage, tomatoes do not recover their nutritional value when kept at ambient temperature. In contrast, they trigger reactions that are detrimental to quality (brown colouring, rapid softening, etc.). The storage time limit for triggering “chilling” reactions is not strictly known.

The wide-ranging origins of tomatoes (and therefore the weather they experience), distribution circuits (imports from Morocco, local production) and the number of variables that come into play throughout the various chains mean that the actual temperature conditions and exposure time the tomatoes experience remain poorly understood. We have therefore decided to conduct a study using data recorders placed in crates dispatched from the producer to the wholesalers, then from the wholesale markets to the distributors. The findings show that storage at 4°C is most commonly seen in refrigerated trucks which are often set to very low temperatures (especially when they are not only transporting tomatoes). Periods of intense cold are therefore either very short periods (transport from a production area to a storage area, or between dispatching platforms), or periods of around 72 hours for transport exclusively by truck (and crossing the Mediterranean in container vessels).

Periods at 12°C generally apply to storage in distribution platform cold stores. This is also the temperature reading for transport by ship (average of 2-3 days to cross the Mediterranean). These periods are quite stable with almost no discontinuity apart from one case of a brief rise in temperature (approximately one hour) to 20°C, probably due to a palette being rearranged before being dispatched to a retailer.

Finally, it should be noted that some tomatoes are subjected to storage periods at high temperatures (30°C) when the fruit is harvested during hot weather and left to stand in warehouse storage areas without air-conditioning before being moved back to the storage platform. Generally speaking, these periods do not exceed 24 hours.

The nutritional composition of the monitored batches varies according to technical itinerary. For instance, the most-affected aspects are vitamin C and carotenoid content (β-carotene and lycopene), as these constituents are highly dependent on how ripe the fruit is. For example, storing Moroccan tomatoes in a warehouse at room temperature for 48 hours allowed them to ripen and, as such, the lycopene content to double (0.7 mg/100g to 1.4 mg). However, the natural variability in batches of tomatoes makes it difficult to precisely assess the effect of different dispatch itineraries. To overcome this, we ran a series of basic storage scenarios on batches of tomatoes from the same production (with one temperature variation) and complex scenarios (several temperatures, short period in chilled conditions, etc.) in air-conditioned chambers; these being typical of conditions measured with sensors. Five examples of increasingly complex case scenarios and their impacts on vitamin C and β-carotene content are shown below.

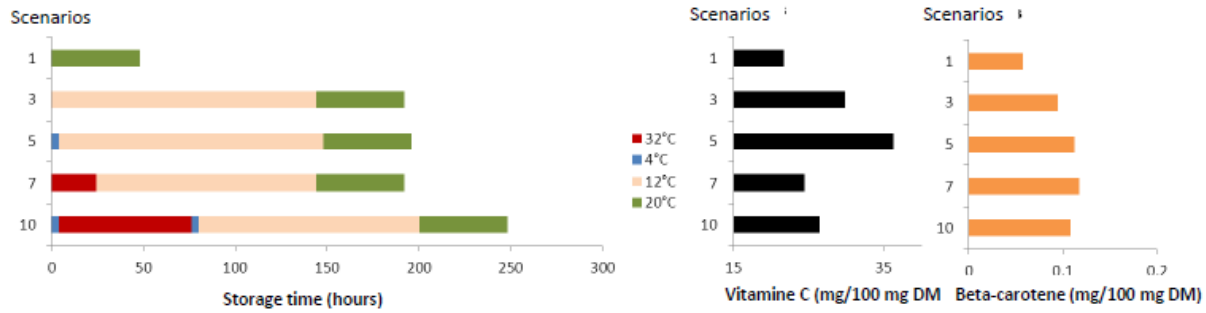


Figure 8: Impacts on vitamin C and β-carotene content for 5 case scenarios

The main findings are as follows:

1- Fibre and folate (vitamin B9) content vary little whatever the treatment.
2- Short periods in intensely cold conditions (4°C) generally have positive effects on vitamin C content (when compared to scenarios 2 and 4 and then 3 and 5). Conversely, long-term storage at 4°C was no better than that at 12°C (comparison between scenarios 4 and 8) and even contributed to reducing β-carotene content.
3- Short or long periods of storage at 32°C encouraged β-carotene content, but they did not deliver any significant improvement in vitamin C content.

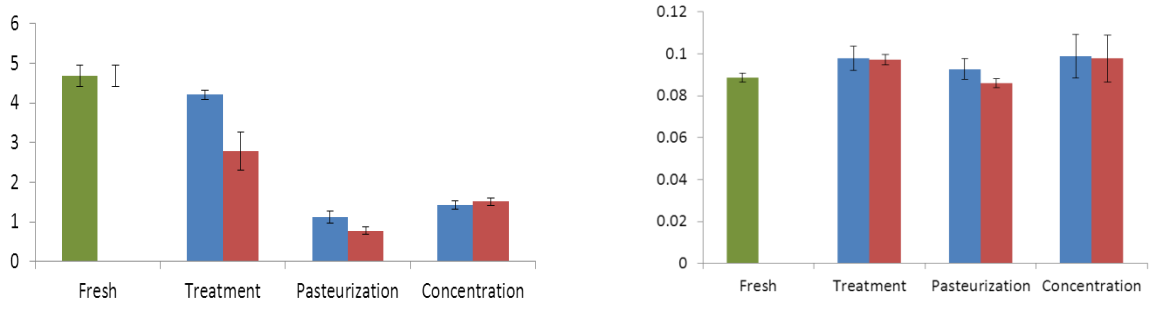
Although the results obtained from these 11 scenarios were reproduced using a single batch of tomatoes, under no circumstances whatsoever do they constitute a representative population on which general rules can be adopted. They do however illustrate that according to conditions encountered in the industry, it is difficult to predict the compositions from the literature and that systematic studies on critical points (the time limit for effects concerning a high or low temperature) must cover a wide range of fruits. Finally, on the whole, it can be considered that the conditions applied only cause slight variations compared to the impact procedures have on thermolabile vitamins in particular, such as vitamin C.

5.2.3 The case of the processing tomato

From harvesting to processing: processing tomatoes are generally picked by mechanical harvesters (similar to combine harvesters) and transferred to gondolas where they pile up (up to a height of 2m) ready for transport. In France, production fields are generally located less that 70km from the processing area. Harvesting can damage them (collisions) whereas transporting them is more likely to

squash them. At the factory, the gondolas are dealt with as quickly as possible, but tomatoes can spend several hours at ambient temperature before they are processed. In any case, no tomatoes destined for processing are transported in refrigerated trucks, and although the temperatures they experience certainly have an effect, this parameter is not worth taking into account as far as the industry is concerned. The state (blemishes) and storage time in the gondola are the two parameters that were monitored and simulated in the laboratory. The control tomatoes, which were hand-picked and transported by crate, were compared to machine-picked tomatoes (therefore partially damaged) that were transported to the processing plant in gondolas (collected on the unloading platform) then processed in the 2 hours that followed. A third batch was put together from part of the hand-picked tomatoes and which were thrown about in standardised conditions (by dropping them from a height of about 2m onto a flat surface) then stored for 24 hours at ambient temperature before processing. After damage to the fruits, the most influential parameter on nutritional quality was storage. This caused a loss of almost half the vitamin C, the latter being the only variable monitored (from folate content, sugars/acids, fibre and carotenoids) to be significantly affected.

Processing: this involves several unit stages that can affect molecules with nutritional benefits. The tomato spends very little time in water (so we can ignore losses that might be due to rinsing) and there is no bleaching stage (enzymes are inactivated by being rapidly heated in a water bath at 70-90°C). The fruits are chopped and sieved (to remove pips and skin) as soon as they enter the factory then rapidly heated to 70-95°C (subject to the chosen procedure) by plunging them into pre-heated tomato juice (continuous flow systems). The puree can be used in different forms, but it is most often concentrated and then sterilised. We monitored vitamins C and B9 (reputed to be sensitive to heat and rinsing) as well as carotenoids which can oxidise at low temperatures. We ran two classic industrial technical operations which help modulate paste viscosity. These were the Hot Break process (tomatoes are chopped and rapidly heated to a high temperature) and the Cold Break process (chopping and maceration below 50°C before heating). Here, again, only vitamin C was affected. For both types of process, the final loss after canning was close to 75%, but the loss happened earlier when the product was rapidly heated (Hot Break). The concentration stage also had an impact. In normal circumstances (when the vitamins have not be destroyed), as that the product has been concentrated 4-times, the vitamin content of the paste (in terms of dry weight) should also be 4-times stronger. However, the paste contains the same amount of vitamins as the puree. The same goes for carotenoids (β-carotene and lycopene which behave similarly with respect to the treatment) with the paste content being the same as that of the canned puree.



Vitamin C (mg/g of dry matter)

Lycopene (mg/g of dry matter)

Figure 9: The effect of treatments on Vitamin C and lycopene content

Storage: generally speaking, the stabilised products are stored at ambient temperature for a period of up to 3 years. Monitoring both time and temperature is therefore required at this stage. As several contradictory studies on the stability of carotenoid content have been published, this was our main target for this study on stability. As such, lycopene content, which was 0.085 mg/g if dry matter during production, was no more than 0.054 mg/g two years later.

This test was conducted in trial conditions, resembling those in industry and using processing tomatoes which are richer in dry matter and more consistent than fresh market tomatoes. Nevertheless, the results obtained must be taken as an example. Only a more comprehensive study focusing on several harvest years and technical processes could produce strong significance to the data introduced to the decision-support tool described hereafter.

6 A decision support tool for diagnosing and simulating

6.1 Methodological approach

The purpose here is to produce a modelling platform to help professionals make decisions about their production and organisation options by giving consideration to nutritional, environmental and socio-economic criteria.

As stated in the introduction, the Life Cycle Assessment approach developed to conduct nutritional, environmental and socio-economic assessments, provided the framework for the decision support tool. This decision support tool (DST) is therefore a common platform intended to be generic, simple, effective and easy to use. The approach is centred on three main phases (Figure 9) defined by taking into account the various LCA stages.

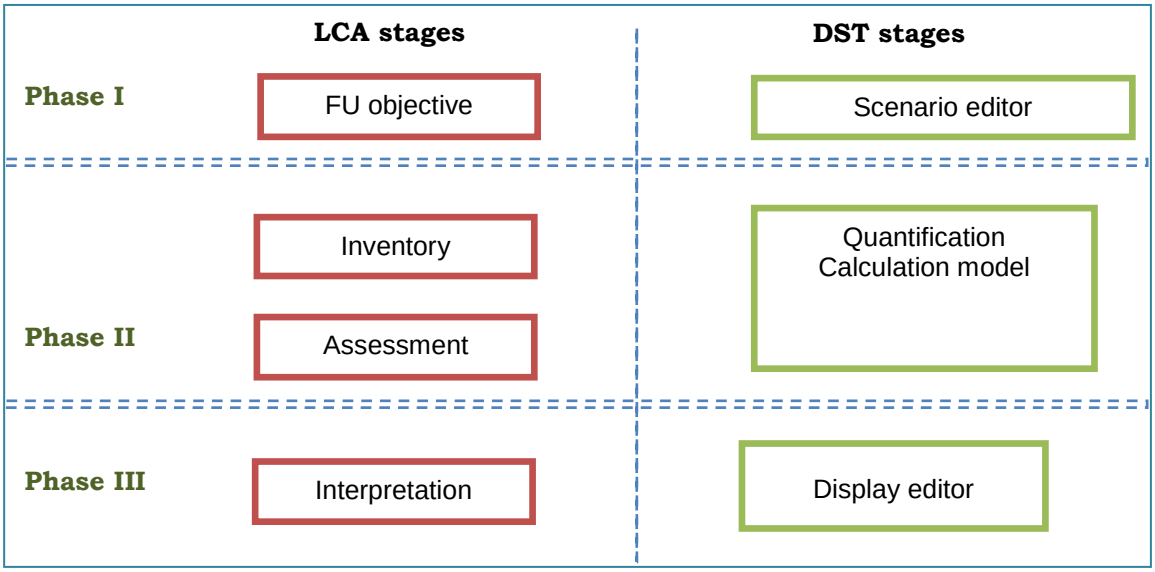


Figure 9: Conceptual approach of the decision support tool

6.2 Phase I: Constructing the scenarios

In its first phase, the DST is primarily descriptive. It comprises a description of the baseline situation (the baseline scenario) which briefly presents the industry (product characteristics, production, storage, logistical and consumption systems). It also includes a recap of the anticipated scenarios. The scenarios are identified based on operational questions from the professional working in the industry.

The common function of the system studied is producing the tomatoes, making them available on the market (transport, processing) and their consumption regardless of the type of tomato, the production location and the growing period.

The functional unit providing a basis to compare the scenarios is:

- one kilogram (1kg) of tomatoes (fresh or processed) available to consumers (in France) for the environmental LCA (ELCA);
- 100 kilocalories (kcal) provided by the product for nutritional quality.

The boundaries of the system studied for the three types of assessment extend from the field all the way through to consumption (cradle-to-grave) and refer to the various activities of the industry's stakeholders (figure 10).

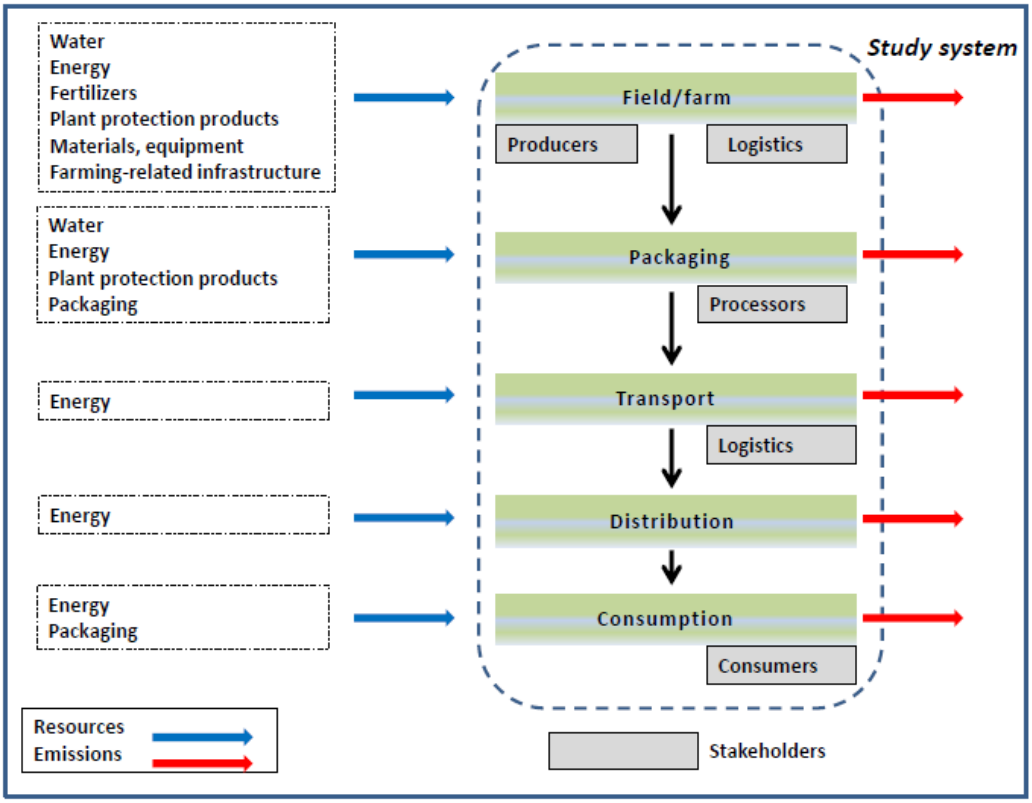


Figure 10: Description of the life cycle stages of the tomato "from-cradle-to-grave"

6.3 Phase II: Quantifying performance and/or impacts

Once the various questions from the professionals are set, we move on to the quantification phase and calculation of potential impacts using the tool. This phase corresponds to the inventory phases (emissions/extractions) and impact assessment.

Designing the decision support tool requires the use of a database. Depending on the flow of materials and energy required to manufacture the product studied as well as the industry stakeholders, the database must be able to firstly quantify the input parameters (substances emitted and extracted, characteristic functions, etc. and secondly, to come up with impact factors quantifying these parameters.

6.3.1 Database choice

The databases generally used for Environmental LCA are based on the product or service's geographical and technological circumstances, or the system to be assessed. FLONUDEP used the Ecoinvent database (Swiss Centre For Life Cycle Inventories, version V2.2; 2010) because it is a generic database with around 4,000 life cycle inventory datasets (procedures). Furthermore, it is recent and the data offers a wide geographical representation (European, even worldwide). As concerns nutrient and social assessments, these refer to simulation data from the FLONUDEP project team.

6.3.2 Calculation method for impacts and indicators

The **ReCiPe** impact assessment method was used to determine the product's (the tomato) environmental characteristics. The potential effects of the life cycle inventory related to the activities performed are expressed through the following indicators:

i) impact indicators describing an environmental problem (global warming, acidification, eutrophication, ecotoxicity, toxicity);

ii) indicators assessing the damage caused (human health, the diversity of ecosystems, availability of resources).

The $SAIN_{FEL}$ (individual score for recommended daily intake for fruits and vegetables) is the nutritional indictor used. It is an aggregate indicator that corresponds to the overall nutritional quality of fruits and vegetables and is expressed in terms of fibre, vitamins C and B9, beta-carotene and potassium.

As concerns the Social LCA, the tool identifies and quantifies the product's (or service) social footprint on the industry stakeholders (the life cycle) by generating the social impacts of capacities.

6.4 Phase III: Displaying the results

This third phase of the tool corresponds to choosing the method to display the results. The results from the various scenarios are presented in the form of tables and graphs, but it is possible to export them to Excel, thus enabling the user to manage them as they wish (to dispose of more detailed results and/or the option of generating aggregated indictors).

7 The sustainability of food products from a consumer standpoint: social aspects more than environmental attributes?

Incorporating the human diet into a sustainability dimension throws up numerous ecological, social, health, and economic challenges. Sustainable food is portrayed as a new paradigm and is correlated to increasing environmental awareness from the perspective of perpetuating food resources in the long term with each stage of the food chain being subject to precise environmentally-friendly standards. Although this preoccupation for the environment highlights the dichotomy between intensive agricultural production and low-input production, it also emphasises the necessity to review a production system that is reaching its limits. Various stakeholders, producers, consumers, manufacturers and researchers are involved in this new quest for a balanced, sustainable and responsible food model with the shared desire to not compromise future generations' access to resources.

The consumer's contribution to sustainable development happens by a change in buying behaviour and consumption. The various approaches employed by stakeholders in the agri-food industry to raise awareness and inform the consumer about the sustainability of products are centred on their communication about environmental aspects using the carbon index or food miles. The study conducted as part of FLONUDEP shows that social aspects of companies can be more important for the consumer.

Price remains one of the most influential indicators for the consumer. The influence of price is undeniable, so determining what price the consumer is ready to pay for health benefits or more environmentally-friendly techniques and/or for more ethical socio-economic systems is therefore of the utmost importance.

To provide some answers to this issue, two consumer studies were undertaken as part of FLONUDEP.

The first study sought to gain a better overall understanding of the way the consumer perceives sustainability criteria in the fruits and vegetables industry and, more precisely, that of the tomato. The second study dealt with specifying the way the consumer decides between the various attributes of the tomato.

7.1 Consumer perception of product-related information

7.1.1 Methodology

Eight hundred people, living in three regions of France displaying different eating habits took part in this survey in 2012 (250 in Ile de France, 250 in Pas-de-Calais and 300 in Languedoc-Roussillon). The breakdown according to age was relatively balanced although young people (20-25 yrs old) were under-represented as were older people (the over 65's) in comparison to the French population (Insee, 2011).

7.1.2 Results: sustainable development, a vague concept

The concept of food product sustainability remains rather vague and poorly defined with the consumer perceiving it in different ways. The FLONUDEP study makes it possible to explore consumer perceptions on sustainability by taking the example of fresh and processed tomatoes. It also allows comparisons to be made between these declarations and buying and consumption behaviour. The study on these two aspects makes it possible to target and challenge the consistency between day-to-day perceptions and practices.

In the consumer's mind, there are many dimensions that are more or less associated with sustainable food. The results of this study make it possible to better target consumer perceptions and identify the main characteristics of sustainable food as seen by the consumer.

7.1.2.1 Information deemed to be sufficient

The concept of sustainable development has been, and continues to be, the subject of unprecedented media coverage which results in consumers feeling some sense of command over the concept. As such, people surveyed considered themselves to be well-informed (54% of respondents) about the question concerning the availability of information on sustainable food. However, 30% considered that they still had too little information. The lack of information can be interpreted as too much information, a lack of information, or even a lack of confidence in the information provided. Indeed, in terms of environmental claims, countless initiatives from companies and distributors display either the carbon index of products or the basket of groceries purchased, or other sustainability indicators such as composition (quality of ingredients and nutritional value), manufacturing by a process that reduces environmental impacts, or packaging in terms of quality and recycling.

7.1.2.2 What characteristics qualify sustainable food?

Based on the literature, exploratory talks and the quantative survey, various dimensions connected with sustainability were examined:

Origin and season

It is generally accepted that in the mind of the consumer, there is a strong link between product sustainability and proximity to the place of production. The concept of "food miles" has institutionalised this connection between sustainability and proximity. As a result, most studies (CREDOC, CTIFL, etc.), show a renewed interest in the origin of products and their proximity which is the basis of the "locavore" phenomenon.

The connection between origin and the sustainability of products is clearly predominantly linked to environmental impacts, but for fruits and vegetables, the CTIFL found that consumers make the link between the origin and organoleptic and nutritional qualities.

The FLONUDEP study clearly shows a strong dimension of food sustainability linked to origin and season. Although the origin of products has been largely identified as a consumer buying criteria for reasons of confidence and quality, today it is seen as an act of environmental protection. Furthermore, it is no longer a matter of 'simply' anchoring products in a territory but also of measuring the distance of

this origin. 76% of the FLONUDEP study sample considered that the origin of products is important while 87% made the link between origin, taste and nutritional quality.

The origin also seems to be linked to production methods and, here, we find the common approximation that closer the origin, the more the production methods respect the environment and health.

Finally, a new development is the connection between origin and season. Technically speaking, even if all products sold are seasonal somewhere in the world, the concept of seasonality where the consumer lives is starting to appear. However, according to the CTIFL, the notion of seasonality is becoming absurd and is pushing the consumer to adopt dietary habits in line with the product offer in the shops. This applies, for example, to apples offered for sale all year round. The introduction of new storage techniques is also behind the loss of seasonality. European apples are on display on the shelves sometimes 13-14 months after being picked whereas the normal storage time in a refrigerated environment is 6 months. New storage techniques can have negative environmental impacts even though they might concern 'local' products.

86% of respondents in the FLONUDEP survey declared taking seasonality into account. In reality, their out-of-season purchases show the opposite.

Organic and Fairtrade as "benchmarks" for sustainable food consumption

"Organic" and "Fairtrade" are two labels associated with sustainable food, probably due to various reasons. As a matter of fact, although these labels are sometimes displayed together on products, they refer to two different types of representations and sets of values. Many studies show that the main reason for buying organic products is not always environmental, but rather a set of heterogeneous reasons including health, taste, how safe the food is, but also family health (especially children), or even respecting traditions (Hughner et al., 2007[14]). Fairtrade appeals more to consumers' social ethics.

Consumers often think that organic farming contributes to protecting the environment (83 % of people surveyed) and although 77% of consumers still consider that eating organic is good for health, environmental dimensions seem increasingly associated with the organic label.

Consumers consider that the "Fairtrade" label expresses social aspects of sustainable development. In the FLONUDEP study, 67% of respondants made the link between sustainable food and organic products and 71% with Fairtrade products. Despite a perception still fluctuating between organics and the environment and organics and health, this label is considered to be a good guarantee of a product's sustainability.

Health

The link between sustainable food and effects on health constitutes the 3rd dimension of sustainable food. Nearly 75% of respondents considered that sustainable food consisted of consuming healthy products. The link between sustainable food and healthy products was assessed as 4 on a scale of 5.

The value for money criteria acts strongly influences consumers' choices and purchases. The high price of sustainable food products linked to higher production costs initially associates them to a more privileged sphere which is expanding despite the challenging economic environment.

7.1.3 What intentions are there to alter buying behaviour?

Changing consumer behaviour over time is very difficult to forecast given the perceived risks and the cognitive investment required. Indeed, many studies have shown that 80% of purchases are routine. This is why the launch of a new product is generally accompanied by major communication campaigns to overcome consumer inertia.

In the FLONUDEP survey, people were questioned about their intentions to alter their behaviour to be more in line with sustainable food.

[14] *Hugner et al. 2007 Who are organic food consumers? A compilation and review of why people purchase organic food. Journal of Consumer Behaviour 6: 94-111.*

More than a third of respondents were not ready to change their habits, which emphasised the gap between awareness about the beneficial nature of sustainable products and their purchase. A quarter of people surveyed responded positively to changing their purchasing practices while a tenth said they would do it if prices dropped, about a quarter expressing no opinion and 10% perhaps considering it.

Changing one's behaviour and values seems increasingly difficult for consumers. In the FLONUDEP survey, some forms of 'sustainable' buying behaviour and consumption were characterised then weighed against attitudes to sustainable food. The possibility of changing behaviour, where the purchases are made, the use of a vehicle when making purchases and the method of waste management were all studied.

It can however be seen that 77% of those surveyed buy their fruits and vegetables in supermarkets or hypermarkets. Purchases at markets or grocers only accounted for 21% of cases. The approximate distance between the first place the fruits and vegetables are purchased and the home varies from less than 1km to 25km, but half of the responses indicated a distance of between 100m and 1km. To make their purchases, French consumers travelled by car (42%) or on foot (48%) with public transport being rarely used.

Nevertheless, there are significant regional differences concerning the mode of transport used. For the two cities of Paris and Lille, respondents preferred to make their purchases on foot whereas three-quarters of those surveyed in Montpellier preferred to use their car. Aside from these urban considerations and the retail density in large cities, we can note the probable cultural effects on the use of private vehicles.

7.2 Consumer decisions between different attributes of the tomato

The topic of sustainable development is still abstract in the minds of consumers who apply this concept with difficulty. As a reminder, the FLONUDEP Project is based on three strands of sustainable development, i.e. an economic and social strand, a nutritional strand and an environmental strand.

The rest of the study aims to identify how important these 3 attributes are in choosing products. Indeed, the consumer is faced with alternative choices of varying complexity which they must appraise and compare. Weighing up between different information is often done to finalise their choice.

After having identified the most relevant information about each dimension of sustainability (environment, health, social ethics and price), the effect of various combinations of these 4 types of information was tested on preferences to identify those that best predicted the consumer's preferences for a product.

7.2.1 Methodology

We have used joint analysis method which makes it possible to identify a person's system of values by analysing the compromises they make when making their choices (Green and Srinivasan, 1978[15]). "This is a statistical method to determine individual preferences through a product's various characteristics" (Javaheri 2009[16]).

The key feature of this method lies in the fact that when an individual is put into a situation where they have to make a choice (for example, comparing two different offers with similar features), they will make a compromise to accept a proposal only when several features of one of the offers is of major importance in their expectations compared to the other.

Tomatoes characterised by their attributes on environmental impact, the producer's social responsibility, nutritional quality and finally, price, were offered to consumers for assessment.

[15] *Green, P.E., Srinivasan, V. (1978). Joint Analysis in Consumer Research: Issues and Outlook. Journal of Consumer Research, vol. 5, n°2, pp 103-123.*

[16] *Javaheri, M. (2009). Analyse expérimentale de la consommation de fruits et légumes. http://hal.archives-ouvertes.fr/tel-00459381/p201*

The table below specifies the forms of each attribute.

Environment	Social	Nutritional	Price/kg
High carbon index Low carbon index	Socially-responsible production Production not socially-responsible	Rich in nutrients Poor nutrient content	€1 €2 €4

Various combinations of these characteristics were proposed for assessment by consumers.

In 2012, a survey questionnaire involved 1,081 people in the main canteens/cafeterias in Montpellier. The final sample comprised 14% of people under 25 years old, 25% between 25 and 34 years old, 24% between 34 and 44 years old, 32% between 45 and 59 years old and 5% over 60 years old.

7.2.2 Main findings: social aspects are more important than environmental aspects

Figure 11 below gives the relative importance of the various factors in consumer preferences.

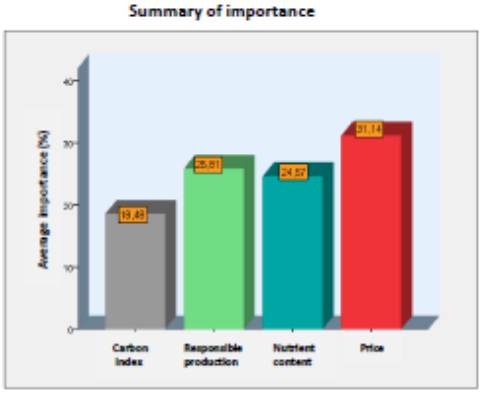


Figure 11: Relative importance of different factors in consumer preferences

This illustrates that price remains an important attribute in consumers' purchasing decisions, accounting for 31% of the product's value while the producer's social responsibility is the second highest-ranking attribute of importance, well above the carbon index. These findings are very interesting because they finally show that people's social preoccupations are much stronger than environmental concerns. The tomato's nutritional aspects figure highly, accounting for 25% in the choices of the consumer which is consistent with the tomato's healthy image and fresh products in general.

In conclusion, we observe that the consumer is conscious of consuming responsibly and pays particular attention to respecting the seasons, geographical origin, production method and the quantity of packaging, etc. Their behaviour is generally influenced by family members and direct acquaintances who constitute immediate and longer-term groups of influence. The consumer is also influenced by information provided by the producers or distributors.

Considering the social or environmental dimension when making a purchase is a sign of responsible purchasing. As such, the individual takes account of the public consequences of their private consumption and uses their purchasing power to bring about changes in society. There is therefore a real challenge for environmental education to be a driver for adopting more sustainable practices. Although the sustainable tomato does not exist for all the criteria, the FLONUDEP guidance tool should help get closer to it.

Given the different results from the FLONUDEP study, it is very difficult to communicate satisfactorily with the consumer on both the information concerning environmental impact, nutrition, and social performance. We have seen that the results are complex and can even be contradictory depending on the criteria used (the high impact on GHG, for example, or the low impact on eutrophication or human toxicity). In addition, the message can be misunderstood (product derived from a socially-responsible company, for example), or there can be an ambiguity in the information. These claims must therefore be based on perfectly clear definitions. Finally, although overall trends concerning the interest of one criteria over another feature in a population, each consumer is different to the other and will focus their attention on the sole criteria they consider to be important and useful. The National Consumer Council estimates that improved consumer information involves several pre-requisites. These include making the methodological bases more reliable, standardising the display format and the areas of work to be explored (costs, controllability of display and link with community and international rights) with a view to improving the process. We could not agree more with this opinion.

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