GLOBAL CHANGE ADAPTATION: WHAT FUTURE FOR SUNFLOWER CROPS AND PRODUCTS? A FORESIGHT STUDY FOR OILSEED CHAINS AT 2030 HORIZON

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ABSTRACT :

A foresight study was carried out to 2030 horizon (15 years), to shed light on the opportunities that will draw the oilcrops and grain legumes, and the areas of growth for the vegetable oil and protein sector. The thinking was organized in four different scenarios, illustrating different logical evolutions of the context and related key issues, under the pressure of demographic, economic and socio-political constraints. The economic value of the protein fraction is a key aspect of the future of oilseeds such as sunflower. However, a saturated market for oils falls within the trend but is not a certainty.

Keywords: Sunflower, oil and protein markets, vegetable oils, Vegetable proteins, oil crops, grain legumes, food demand, foresight, scenarios.

INTRODUCTION

What will be the outlets that pull the oil and protein crops in 2030? What will be the areas of growth for the oilseed sector? The reflection was launched by the French sector of oilseed crops and grain legumes, wondering about the recent evolutions in the relative economic value of oil and protein fractions in oilseeds, rebalancing the economic interest of the two co-products, oil and oilseed cakes.

Questioning "vegetable oils and proteins" brings back to the fundamental historical development of oil and protein crops in Europe, which is still very dependent on imported vegetable protein (Visser, 2013). But with a major change: when soy is still the market leader in plant proteins, now palm is leader on oils. Given this dynamic competitor from Asia, which produces more than 4 tons of oil per hectare per year when a sunflower crop produces about 1t/ha, the protein fraction is obviously part of the future of the oilseed crops. But the question needs to be reformulated in view of the demand both in quantities and qualities. Oils and vegetable proteins (and their origin commodities) are among the most traded agricultural commodities in the world: over 50% of global oilseed production is exchanged, when only a third of the sugar and 10% of cereals are (Mittaine and Mielke, 2013). The question must therefore be addressed, for part at global scale and at regional scale, since "regional" policies can strongly direct productions, as seen in the case of biofuels.

A working methodology based on the analysis, and a synthesis in the form of scenarios

The reflection was organized along the lines of strategic foresight methods (Godet M. 2007). A first step was to describe the “prospective system”, by situating the heart of the vegetable oil and protein system in its context. The experts group developed a representation of the flow diagram of vegetable oils and proteins and their products, linking 21 elements of the agro-industrial system of oils and proteins, in a surrounding context described through 13 environment factors, or "regulators". Then, the various elements of this system were the subject of an information review. The analysis of past and present dynamics led the working group to make assumptions (145 in total) for 2030, in the trend or in rupture, for each factor or key variables.

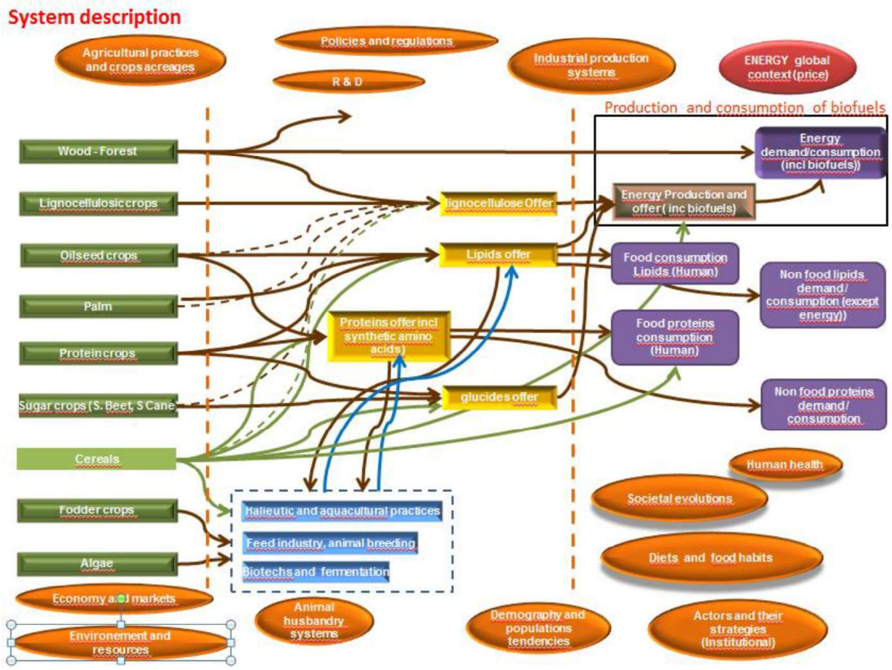

Figure 1: the protein-oil system and its context

Table 1 driving and main secondary assumptions

MAIN ASSUMPTIONS	2013	SC1 Chaos	SC2 Blocks	SC3 Trust	SC4 Climate rupt
Population	7,2	8,9	8,4	7,9	8,9
agricultural yields progress		stagnation	weak	moderate	stagnation
Per capita animal proteins consumption		low	moderate	high	low
Political behaviours regarding global change		passivity, everyone for himself	blocks policies	cooperation	cooperation
Economic growth		weak	moderate	high	moderate
petroleum price $/ barel // $/ton	105 //770	50-70 // 365-511	60-80 // 450-610	135/150 // 950-1100. contrasts between regions	135/150 // 950-1100 . contrasts between regions
animal protein consumption g/cap/day					
China	37	39	46	46	41
India	14	20	21	36	18
Africa	14	16	26	26	18
Europe	67	49	54	65	36
USA	70	55	61	66	43
World	31	29	34	39	29
Palm oil for food consumption MT/yr	41	"200MT"	42 à50MT	50MT	
nutritional recommendations are taken into account	0	no or poorly	yes	yes --> oméga3	yes --> oméga3
EU policies on biofuels	0	biofuels not mandatory	energy directive maintained/ biofuels mandatory	energy directive maintained/ biofuels not mandatory	
reinforced regulations regarding sustainability	0	no	carbon tax in Europe	yes, standardization	carbon tax and standardization
GMO regulations		deregulated	no crops no use in Europe	constraints lifted	constrainsts partially lifted
antibiotics uses in feed		free	prohibited	prohibited	?
green chemistry, biorefinery	0	stagnating	strong develpt	strong developt	strong developt

The construction of the structure of the scenarios was done using "morphological analysis," by assembling assumptions about different dimensions or variables by empirical judgment of the consistency, each scenario being based on one or more driving assumptions on key factors for the demand evolution. Table 1 shows notably the first 5 levels of assumptions assembly, which determine the overall level of demand and the socioeconomic tone, giving the thread of each scenario. The scenarios were then written in text form, as a first step of consistency check. A quantitative assessment was then carried out to check the consistency of the assemblies of assumptions made on variable estimates. These four scenarios, which illustrate different logics of context evolution and major issues, are summarized in the box below.

FORESIGHT STUDY 2030

VEGETABLE OILS AND PROTEINS

4 scenarios as thinking framework

Scenario 1: "Towards Chaos": Economic and political crisis, food tensions, competitions and growing inequalities

Facing the strong world population and the tangible effects of climate change, the situation is tense to meet food demand. The economic crisis, generating a climate of tension, insecurity and general impoverishment, does not allow the adoption of international agreements on long-term policies (resource conservation, environment, renewable energy, health ...). Animal proteins are a luxury: their consumption is declining in Europe (where the vegetable proteins are better accepted) and tops out elsewhere. With depressed energy prices, biofuels of first generation remain only to sell the oil surplus from palm and soy. The rising cost of food leads to increased use of plant proteins. Regarding vegetable oils, palm oil, abundant and inexpensive, dominates in the food business.

Scenario 2: "The might of the blocks": Regional Policies and bilateralism

Climate change leads to contrasting effects between regions: due to divergent interests, international negotiations are blocked. Europe and the most affected countries implement unilateral policies against climate change, in a latent protectionism atmosphere. Yields - and global production – increase slowly, for a population that is growing by 15% between 2013 and 2030. The economy keeps pace with the population and the standard of living is maintained on average. In Europe, society's demands on sustainability and health led States to develop renewable energy (including biofuels), to better exploit the potential of territories and to regulate: restrictions on greenhouse gas emissions and carbon tax. Biorefinery at regional scale and non-food uses of agricultural resources are essential. Veganism rises in Europe while consumption of animal protein progresses in China and Africa. Palm oil is used in chemistry, especially in Southeast Asia, and for biofuels.

Scenario 3: "Trust": International cooperation in preventing climate change

The Nations sense the threat of climate change and integrate it in their policies, creating an international cooperation to address climate, food and energy challenges, while maintaining free trade. Green Growth is launched, based on advanced R & D and the establishment of trading standards (on products, processes and production conditions) and accompanying measures, where Europe plays leader. European consumers are aware of the nutritional recommendations and of the carbon impact of production and consumption modes, and are turning to a low-impact diet. Quite the opposite, the improvement of living conditions linked to moderate population growth and economic affluence leads to increased consumption of animal protein in many countries (Africa, China, but also India) blowing the demand for animal feed. Soy is widely grown for feeding livestock. The oleochemistry and biofuels, driven by R & D and high energy prices, are growing strongly worldwide, especially in Asia on palm oil basis.

Scenario 4: "Climate rupture": Measures for savings and forced cooperation because of climate and food tensions

The strong growth of the world population and the effects of climate change put agricultural production under pressure and cap yields. This leads states to negotiate and cooperate in emergency as on environmental policies and at the level of technology transfer and of the distribution of economic efforts between the South and the North. Constraining measures target carbon balances and GHG, playing both on production processes through standardization and on consumption through a generalized carbon tax. Energy is taxed to finance the development of alternative energies. Advances in R & D are put forward to meet the constraints and generate green growth, opening applications to GMOs, green chemistry, the development of a circular economy with local bio-refinery. Initially driven by economic growth, the development of animal protein consumption proves unsustainable and quickly reaches limits in Africa and Asia. European consumers, made aware of issues of sustainability and health by the authorities, opt for a diet less rich in animal protein.

What developments for vegetable oils and plant proteins outlets?

In terms of vegetable oils, the increase in food demand remains relatively limited, from 133 Mt (million tons) in 2013 to 156-165 Mt in 2030, an absolute increase of 23 to 32Mt, relatively limited compared to the growth capacity of the palm oil production. We can therefore expect strong competition in the vegetable oil market with two heavyweights: the palm oil supported by its strong competitiveness in production cost per ton, and soybean oil, driven by the strong demand for protein for animal feed or food.

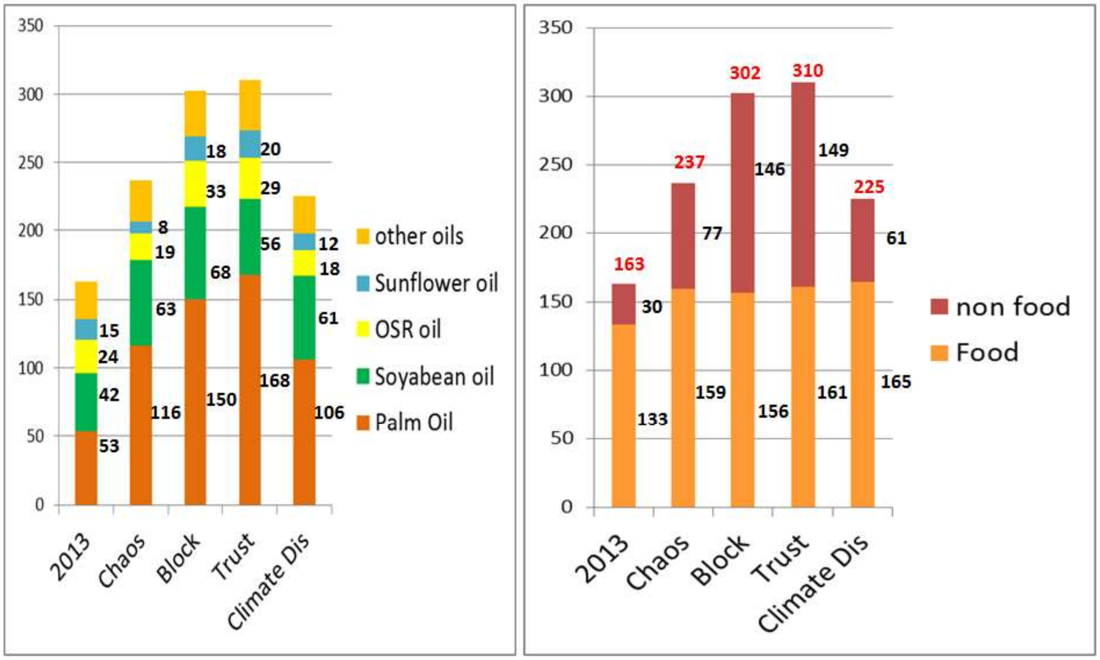

Figure 2: Global production and use of vegetable oils

The conditions for the development of non-food uses of oils are very different between scenarios: excess oil may be real, with need to dispose of surpluses for cheap non-food outlets (biofuels in Sc. 1 " chaos "), or artificial in case of real economic dynamics of non-food uses, either from a high energy market (Sc. 3" Trust "), or from technological innovation and / or incentives policies (Sc. 2 "Blocks"). In the case of Sc. 4 "climate rupture" excess oil over the food needs is relatively limited in a context where the resources scarcity, actual or of regulatory origin, makes nonfood uses economically attractive. This shows that if the strong growth of oil production seems to be a trend, the excess of the production is obvious in Sc. 1 only, where uses at low price only are possible, due economic depression. In other scenarios, noble non-food uses ensure alternatives for consumption and growth in an unbalanced world between scarce resources and the needs of an active economy. However, in the context of Sc. 1 depressed market, the development of palm could be challenged by soybean oil, as co-product from the production of protein for livestock. In scenarios with high oil prices and encouraging biobased products, palm development could be based on green chemistry, provided production is compatible with constraints related to climate change, at least in regulated scenarios (Sc.2, 3 and 4).

That said, the various oils are not completely substitutable and their technical and nutritional characteristics must also be taken into account. For example, the needs in short chains omega 3 fatty acids (alpha linolenic acid) are probably not covered today by soyabean and rapeseed production, or just covered taking into account other sources. In future, covering alpha-linolenic needs seems to be no difficulty only in scenario 3, with the lowest population.

The overall growth of food proteins of animal origin is estimated between 11 and 32 million tons of (pure) protein depending on the scenario, 26 to 39% more than in 2013. The multiplier effect of the consumption of animal products appears very clearly because of the conversion of animal proteins into vegetable proteins needed to produce them: from +52 to +141Mt (including fodder) or +16 to +41% depending on the scenario. Whatever the scenario, the growth of plant proteins for animal feed is high and exceeds the human food destination, but much more pronounced in Sc.2 and 3, more demanding in animal protein, than in Sc. 1 and 4, where the increase in materials rich in protein (fodder excepted) is almost evenly distributed between feed and food.

Table 2: Quantities of vegetable protein to meet demand in the four scenarios

	2013	SC1	SC2	SC3	SC4
Million tons of protein	**Present**	**Chaos**	**Blocks**	**Trust**	**Climate rupt**
Feed fodder	112	153	148	162	129
Feed "rich in proteins"	**227**	**264**	**315**	**316**	**261**
Food	**139**	**174**	**159**	**146**	**168**
ratio Food/(Feed rich. + Food)	**0,38**	**0,40**	**0,33**	**0,32**	**0,39**

Regarding vegetable protein for human nutrition, Sc. 3, which combines economic growth, low population growth and “meat” dietary habits shows the lowest increase (+5.2 %), followed by Sc. 2 (+ 14%). In Sc. 1 and 4, the increase exceeds 20%. The ratio "Food" proteins/ Protein concentrated "Feed + Food" proteins shows a discrepancy between scenarios 1 and 4 on the one hand, where the relative weight of vegetable protein for human consumption increases, and scenarios 2 and 3, where it decreases.

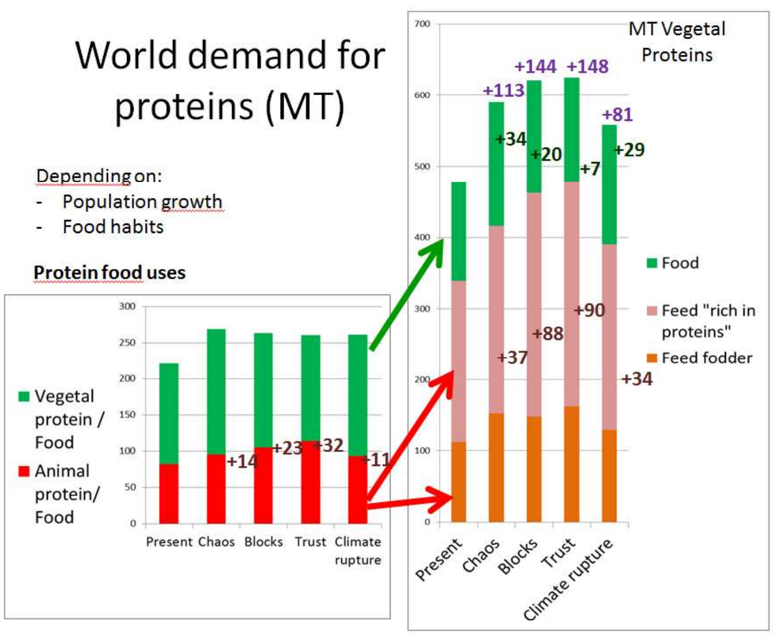

Figure 3: Evolution of demand for proteins in the 4 scenarios

The vegetable proteins that would be provided in the various scenarios are not targeted to the same uses or in the same proportions, and in rather different market conditions: Sc. 3 "Trust" demands masses of proteins for animal feed, without differentiation on the GMO origin regarding Europe, but with more regular qualities, notably because of the disappearance of antibiotics in animal production. The growth of plant proteins for food is the lowest, but also more qualitative from a nutritional point of view, and more "technological" with an R & D driven by the needs of wealthy clients and / or with special needs (elderly, athletes). The vegetable protein is desired for nutritional and technological properties and image. Sc. 2 "blocks" demands for livestock protein masses too, but this time with differentiation of Europe, on the GMO origin and on the nutritional quality through technically more restricted feed system. The growth of plant protein for food is higher than in scenario 3 but with the same "nutritional and technological" profile globally. Sc. 1 "Chaos" demands protein masses for breeding, but for animal feeding systems with few constraints on technical practices, guided mainly by production costs reduction. As for vegetable protein for food, their development is driven by the preoccupation to offer cheap alternatives to animal proteins to impoverished populations, either as raw or minimally processed vegetable products, either as vegetable industrial products or combining animal and vegetable proteins. The role of plant protein is primarily economic. In Sc. 4 "climate rupture," the technical constraints on animal feeding are at an intermediate level and above all guided by the carbon balance sheets. Regarding food, the quality / price ratio is more strongly driven by the dietary and nutritional considerations and health concerns, and respect for the environment (image). At last, the development of aquaculture, with specific protein needs, is a constant of the scenarios.

Will the production be able to follow the demand?

The assessment of the demand in different contexts is not enough: we must ensure that supply can follow, taking into account the constraints on production. The calculations allowed us to assess the needed acreage to meet the demand for our scenarios in 2030(table 3).

Table 3 *orders of magnitude* of cultivated acreage development required in the 4 scenarios

Acreages in million ha	2013	SC1	SC2	SC3	SC4
world cultivated acreage, foddder crops excluded	1287	1461	1472	1362	1457
world cultivated acreage, fodder crops included	1534	1767	1764	1656	1731
world cultivated acreage variation, fodder crops excluded		**174**	**185**	**75**	**170**
cultivated acreage variation fodder crops included		**233**	**229**	**122**	**197**

Given the assumptions, between 75 and 185 million more hectares would be needed to meet the needs for "monogastric" quality feed, and from 122 to 233 including forage crops. The continuation of the pace for land reclamation observed between 1961 and 2000 (rate of 3.75Mha/yr on average) would make 67.5 million hectares by 2030 (18 years). The reverse calculation shows that the land reclamation rate required for the consistency of each scenario would be respectively 3.5, 3.4, 1.7 and 2.9 times the rate of past decades. The likelihood of those figures is subject to discussion, especially with depressed economy. The limit of these extensions of cultivated acreage also lies in the deforestation and greenhouse effects, even if part of the effort can be done without deforestation (INRA CIRAD, 2009). Pursuing further the reflection shows that balancing supply and demand always questions the development dynamics and sometimes asks to reconsider some assumptions, particularly in terms of ambition on improving the diets protein content. The strategic aspect of improving yields at world level (particularly protein yields) is highlighted, and the importance of climate risk in terms of global average yields evolution.

Meeting the needs will be much harder for vegetable proteins than for oils and fats, and will require to play on all levers: food consumption level, waste reduction, productivity.

So it is very clear that protein production is an important part of the future competitiveness of oilseed crops, among them sunflower.

How changing context might affect the competitiveness of different oil & protein crops?

The scenarios highlight issues and technical and scientific challenges that the different crops and agro-industrial sectors can meet more or less easily. We suggest in table 5 an interpretation of the specific characteristics of sunflower as strengths or weaknesses in the different scenarios, i.e. as existing advantages or areas of progress through R&D or value chain organization.

Table 4: composition, protein and oil yields for major crops

Composition, yields, oil and protein yields for main crops/ yields						World (FAO)			Europe (FAO)		
Crop	%	% on product for use				Average yield 2009-2013	aver. oil yield	aver. protein yield	Average yield 2009-2013	aver. oil yield	aver. protein yield
	DM	starch	oil	protein	others	t/ha					
soya	89%	5,7%	18,9%	35,2%	29%	2,5	0,5	0,9	2,65	0,50	0,93
sunflower	93%	1,2%	44,5%	15,4%	32%	1,2	0,5	0,2	2,33	1,04	0,36
rape	92%	3,1%	42,6%	19,3%	27%	1,9	0,8	0,4	3,56	1,51	0,69
pea	87%	44,4%	1,0%	20,7%	22%	1,6		0,3	3,82		0,79
maize	87%	63,7%	3,6%	7,9%	12%	5,2	0,2	0,4	9,36	0,33	0,74
wheat	86%	59,3%	0,0%	10,8%	15%	3,1		0,3	7,15		0,77
Forage and Silage alfalfa	20%	0,0%	0,0%	4,0%	16%	22,0		0,9	42,50		1,70
Forage and silage, maize	23%	3,5%	0,6%	1,9%	17%	34,6	0,2	0,7	39,60	0,24	0,75
Forage and silage, sorghum	28%	0,0%	0,5%	2,3%	25%	20,4	0,1	0,5	35,20	0,19	0,81
Forage and silage, rye grass	17%	0,0%	0,0%	2,5%	14%	10,3		0,3	9,60		0,24
Forage and silage, clover	17%	0,0%	0,5%	4,2%	12%	34,1	0,2	1,4	23,20	0,11	0,97

Table 5: Sunflower characteristics, Strenghts (S) and Weaknesses (W) in scenarios (N = Neutral)

Sunflower characteristics	*level*	SC1 Chaos	SC2 Blocks	SC3 Trust	SC4 Climate rupt
Dependance on nitrogen	medium	N	S	S	S
Dependance on pesticides	medium	N	S	N	S
Rusticity	high	S	S	N	S
Compensation capacities	weak	W	N	N	W
Protein digestibility/ feed	high (dehulled)	S	S	S	S
protein digest & quality/ food	???	S	N	N	S
ability to dehulling	good	S	S	S	S
miw oil and protein specy	44%oil/15%Pi	W	N	S	S
of fatty acids profiles	yes	S	S	N	N
yield level	relatively low	W	W	W	W

Some issues are common to all scenarios: it is the case for the protein economy, i.e. both protein productivity and efficiency of use of the produced proteins. The protein yield per hectare is a fairly discriminating criterion between species, which will play depending on the relative performance of crops in the different parts of the world. Only forage legumes such as clover or alfalfa today exceed a ton of protein per hectare. If these species are now mostly devolved to ruminant animals, protein extraction can change things and forage legumes competitiveness could increase, both in the field of conventional feed and in the area of concentrates and protein isolates. Then come pulses and soybeans, which reach protein yields of around one ton/ha, followed by rapeseed (0.4 to 0.7 t/ha) and sunflower (0.2 to 0.4). Their global competitiveness will also come from their co-product, oil or starch. In this regard, sunflower is not very competitive: global yields are the first priority, before a specific focus on protein yields.

In the scenarios that show a significant development of the biorefinery (Sc. 3 and 4), the different species ability to easy extraction of vegetable protein may be an advantage. From this point of view, the pulses already fall in well-established industrial processes, while the extraction of protein from oil crops species will require changes in industrial processes, to avoid the protein fraction degradation in the present crushing-oil extraction process.

The efficiency of proteins use in animal feed is already a strong competitiveness criterion whose importance is expected to increase, both for economic and environmental reasons. Sunflower progressed in this aspect by including dehulling in the process and developing cultivars more adapted to dehulling. Alternative biorefinery processes for soft and direct oil and protein extraction would be an area of progress for sunflower.

The functional and technological properties of proteins from different species will be a determining criterion, especially as uses will be advanced in nutrition (health food: Sc.3 and 4) and / or technology (use of vegetable protein in food industries for their functional qualities and as substitute for animal protein: Sc.1, 2 and 4). Today the characterization of plant proteins of species grown in Europe, including sunflower, is still limited. These qualitative aspects also play in the ability of different species to meet the needs of aquaculture.

As for oil crops, fatty acids profiles could contribute to differentiate species on the edible oils market. Sunflower remains an oil crop first, and the past and current works for cultivars with specific fatty acids profiles, like High Oleic, or High Stearic High Oleic, or low saturated profiles, etc… will certainly play significantly in its future competitiveness. Regarding human nutrition, minor compounds like tocopherols are also a way to develop the sunflower attractiveness as edible oil.

Other issues and challenges relate to some of the scenarios only. Thus, the production of vegetable protein for human consumption is much higher in Sc. 1 and 4, and should quite naturally benefit pulses and soya, which are already current in the eating habits of many countries, like India, which may well become a structural importer. The fact that sunflower seeds do not content anti-nutritive or toxic compounds gives good opportunities for food uses, even if its amino-acid profile is low in the essential amino-acid lysine. Perhaps more attention could be given to proteic and amino-acids profiles, like for amino-acids until now.

Sc. 2 "blocks" presents a huge challenge for supplying Europe with non-GMO protein, which would lead to make better use of the European territory with the most suitable species and production systems to this objective. Sunflower could well contribute to this challenge, due to a large set of non GMO cultivars and to its rusticity or ability for cropping in contrasted conditions.

The synthetic nitrogen fertilizer requirements for agricultural production would penalize rapeseed, and sunflower too, to a lesser extent, and would favour grain legumes, forage legumes and soybeans in scenarios setting either carbon taxes (Sc. 2 and 4) or restrictive production standards on nitrogen and carbon energy (Sc. 3). Sunflower is relatively nitrogen efficient, and developing this characteristic would be advantageous in 3 scenarios at least.

Developments related to climate change will play in contrasting ways in different parts of the world. In Europe, more stressful conditions are expected. Heat peaks and drier prolonged periods in spring and summer would disadvantage spring crops in rainfed conditions.

Sunflower has the relative advantage of some rusticity, but its compensation capabilities are limited by the nature of its yield components.

The future competitiveness of different crop species depends on many factors (economic, political, climatic, social ...), who will play differently depending on the regions of the world, and whose the result is difficult to imagine. We venture to offer a synthesis of the outlook for different species according to their current characteristics and without assuming the future success of any current or future research and development measures (Table 5).

Table 6: Crops potential progression by 2030, based on their current features.

Crops potential progression by 2030	SC1 Chaos	SC2 Blocks	SC3 Trust	SC4 Climate rupture
WORLD				
Rapeseed	-	++	+	-
sunflower	-	+	+	-
Soyabean	++	+++	++	++
Grain legumes	++	+++	++	+
EUROPE				
Rapeseed	-	-	=	--
sunflower	-	--	-	--
Soyabean	+++	+++	++	+++
Grain legumes	+	+++	+++	+++

Table 7: Challenges for Sunflower crop chain	**SC1 Chaos**	**SC2 Blocks**	**SC3 Trust**	**SC4 Climate rupt**
Crop adaptation to climate change				
Yield T/ha & economic competitiveness				
Protein yield/ha				
Nutritional quality of oil				
Soft process for protein and oil extraction / biorefinery				
Uses of proteins for human nutrition and food industries				
priority level	*secondary*	*medium*	*high*	

This outlook may appear as pessimistic for sunflower; it shows the importance of the challenges. Compared to other sources of oil and/or proteins, sunflower is actually disadvantaged by its yield level. But we may consider that it has two main categories of assets, which are on one hand its rusticity, which makes it suitable to make profit of very diverse conditions (relatively dry, short seasons, double seasons, etc…), where other species are not suitable or not more profitable, and on the other hand specific characteristics regarding quality for oil and probably for proteins. We may attempt to propose priorities between the main challenges for sunflower in the 4 scenarios, as a preparatory step for further reflections for elaborating R&D strategies (table 7).

Conclusions: Is the protein fraction the future of oilseeds?

It seems clear that the economic value of the protein fraction is a key aspect of the future of oilseeds such as sunflower. The future tension for proteins at world scale appears quite certain. At the first level of approach, the yields and protein yields of the different crops will determine their competitiveness for mass uses, including animal feed. At the second level, the issue of nutritional and functional properties of proteins from oilseeds must be considered, with a vast field of exploration to enhance uses with higher added value, in human nutrition, feed, and technology. From this point of view, soy is much more advanced than rapeseed and sunflower and grain legumes. The effective use of proteins from sunflower will also require technological research and adaptations of industrial extraction processes.

That said, the scenario of the oil flood is a trend ... but not absolute certainty, especially if oleochemistry shows economic developments in Asia. Vegetable oils are noble natural materials which may be used in many ways, depending on their fatty acids profiles, the first one remaining food for which sunflower oil has well-established qualities.

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