The Global GM Market

Implications for the European Food Chain

An analysis of labelling requirements, market dynamics and cost implications

by

Graham Brookes (***Brookes West, UK***)

Neville Craddock (***Neville Craddock Associates, UK***)

Professor Bärbel Kniel (***Biotask AG, Germany***)

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Table of contents

Executive summary and conclusions

This report examines the feasibility and cost implications of delivering and maintaining 'GM avoidance' policies in the EU food and feed supply chains.

Relevant crops

The current GM versus non-GM market focus relates to four crops: soybeans, corn, cotton and oilseed rape, where GM crop plantings accounted for 26% of the global area planted to these crops in 2004 (51%, 12%, 24% and 15% respectively for soybeans, maize, cotton and oilseed rape).

Global trade of these crops and main derivatives are dominated by GM origin material (inclusive of co-mingled GM and non-GM material: 90% of soybean trade, 80% of maize trade, 70% of oilseed rape trade and 45% of cotton seed trade). However, whilst most soybeans and its first stage derivatives used in the EU are derived from imports, the vast majority of maize, oilseed rape and cotton seed used is derived from domestic (largely non-GM) production.

The current EU non-GM market

Current EU requirements for non-GM ingredients of maize and soybeans (i.e. where buyers actively request that supplies are certified as being non-GM) account for about 14% to 17% of total soybean/derivative use and 25% to 29% of total maize use.

For oilseed rape and cotton seed, there is no real EU GM versus non-GM market. In the case of oilseed rape, no GM variety is currently approved/registered for commercial cultivation in the EU. Hence, all current supplies of oilseed rape used in the EU are non-GM. In the case of cottonseed, the small market is similarly largely serviced by domestic non-GM supplies (and some imports from non-GM growing countries).

The primary source of non-GM soybeans/meal has been Brazil.

Where the GM adventitious presence threshold applied has been 0.9%/1%, price differentials, over the last two years, have tended to be in the range of 2% to 5% (i.e. non-GM soy has traded at a higher price than GM soy). The current price differential is about 4%-5%. When tighter thresholds and a more strict regime of testing, traceability and guarantees are required (e.g. to a threshold of 0.1%), the price differential has been within a range of 7%-10%.

Non-GM supply: the future

Soybeans

Our analysis (see section 4) of current non-GM supply availability, trends in plantings to GM versus non-GM soybeans (globally and more specifically in Brazil) and the approvals process for growing GM soybeans in Brazil, suggests that the availability of non-GM soybeans from Brazil is likely to fall substantially in the next 1-3 years, and that the price differential between GM and non-GM soybeans (and derivatives) is set to widen significantly. More specifically:

- The Brazilian government has now formally approved the planting of GM soybeans. This will facilitate the further multiplication and allow the marketing of seed suitable for growing in Brazilian conditions containing the GM herbicide tolerant trait, rather than farmers using imported (smuggled) seed from Argentina. This will make the planting of GM soybeans additionally attractive to more Brazilian soybean farmers and extend the planting of GM soybean cultivars into more northerly Brazilian regions[1];

- Given the lack of farm level price premia for non-GM soybeans and the popularity of GM glyphosate tolerant soybeans (because of the farm cost savings obtained) amongst soybean farmers in Brazil (where over 20% of the 2004 crop was GM), it is highly probable that the availability of non-GM derived soybeans/derivatives from Brazil will fall significantly in the next year or two. The farm level benefit of using GM soybeans in Brazil relative to non-GM soybeans is between €23/ha and €56/ha (between €10/tonne and €24/tonne). To keep the average Brazilian soybean farmer growing non-GM varieties, it is likely to require a price premium (relative to GM soybeans) of between 4.2% and 10.5%. Adding this to the existing post farm price differential for non-GM soybeans suggests that the potential EU level price differential for non-GM soybeans relative to GM soybeans will increase four-fold to between 8% and 20% for 'soft IP' soybeans[2], and double, to between 13% and 25% for 'hard IP' soybeans[3];

- Any increase in the share of the Brazilian soybean crop accounted for by GM cultivars, especially into more northerly regions, will increase the chances of co-mingling of GM and non-GM crops, especially in the post-farm transport, storage and processing sectors. This will probably lead to a greater number of buyers of non-GM derived material having to initiate more stringent controls on supplies to minimise the chances of adventitious GM presence occurring (i.e. increased use of 'hard IP' systems). This will add further to the cost of sourcing non-GM soybeans (and derivatives) relative to the price of the GM-derived alternative.

Oilseed rape

Non-GM oilseed rape dominates EU production and usage, largely based on EU non-GM origin production. No GM oilseed rape is expected to be grown commercially in the EU in the next 1-3 years. Although GM origin products dominate global supplies, non-GM supplies have been available in reasonable volumes from countries such as Australia. In the next 2-3 years, this balance of GM versus non-GM supplies on global

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[1] A number of varieties suitable for growing in the Central and Northern regions of Brazil containing GM herbicide tolerant technology are already available for planting in 2005/06

[2] **Soft Identity preservation**: refers to beans or meal that have been sourced and certified as coming from non-GM growing regions (generally within Brazil) and are subject to limited testing / verification procedures or are not accompanied by guarantees / certification as to the precise non-GM status (i.e. no threshold levels for possible contamination (adventitious or otherwise) is given by the supplier). 'Soft IP' soybeans or meal are usually tested only once and if found to be below the legal 0.9% threshold continue to be sold as non-GM supplies to appropriate buyers and if found to be above the 0.9% threshold are diverted to customers that are indifferent to the origin of their raw materials

[3] **Hard Identity preservation**: supplies that have strict IP systems from point of production through the supply chain and which may operate to stricter threshold levels for adventitious presence of GM-derived material (e.g. 0.1%). Regular testing through the supply chain often occurs to ensure that supplies meet buyer specifications

markets is unlikely to alter significantly. Overall, EU oilseed rape consumption will continue to be based on domestic non-GM sources.

Maize

Whilst supply availability of non-GM maize is limited on global markets (and is likely to decline further in the next 1-3 years), non GM maize dominates EU production and use. EU plantings of GM maize are expected to increase in the next 1-3 years but will continue to account for only a very small share of total production. Therefore, those wishing to procure and use non-GM maize and derivatives are likely to find limited, additional difficulty in accessing certified non-GM sources of supply. Price differentials between GM and non-GM maize/derivatives may increase marginally (reflecting increased need to check the non-GM status and to ensure segregation) but can be expected to remain no higher than 3% to 4%.

Non-GM policy: cost implications

Table 1, Table 2 and Table 3 summarise the nature of non-GM ingredient policies and their supply availability and cost implications for a selection of food and feed products[4]. This covers both the current market position and likely developments in the next 1-3 years. The key points to note are:

- Almost all of the additional costs involved in using certified non-GM raw materials have been borne by the supply chain up to (but not including) the retail sector[5];

- For a number of food products, where incorporation rates of relevant ingredients are low (e.g. chocolate confectionery and biscuits, pizza and ready-meals) the additional raw material cost of switching away from GM-derived ingredients has been relatively small. No significant changes to this position are expected in the next 1-3 years;

- For margarine manufacturers, the switch away from GM-derived ingredients is adding significantly (over 16%) to raw material costs. At the EU level, this is adding possibly up to €85 million to the annual raw material costs to the sector[6]. This is also likely to continue in the next 1-3 years;

- For producers of poultry meat, whilst the additional costs associated with using non-GM protein (soymeal) in diets has added up to 2% to feed costs (at the EU level, adding between €10 million and €50 million to annual feed raw material costs[7]), the negative impact on profitability has been more marked (up to -7%). In the next 1-3 years, these costs are likely to increase significantly (at the EU level, adding between €41 million and €129 million to the cost of feed raw materials), potentially resulting in profitability losses of 9%-29%. These levels of losses are likely to be unsustainable and continuation of a non-GM protein

[4] Additional detail and other products are examined in section 5
[5] Retailer costs, where applicable have mainly been associated with testing for the presence of GM DNA in products
[6] Based on EU margarine production of about 2.19 million tonnes and an assumed 70% of this covered by a non-GM ingredient policy
[7] Based on total EU poultry feed production (inclusive of the egg sector) of 36.8 million tonnes and an assumed 36% of this having a non GM protein ingredient requirement

feed policy will probably require buyers of poultry meat to pay higher prices to cover the additional raw material costs;

- There are a number of ingredients used in food and feed products (albeit at very small incorporation levels) that are derived using enzyme and fermentation technology based on genetically modified micro-organisms (GMMs). Any move to avoid the use of such ingredients (if, for example, this category of product were to be included within revised provisions of the EU labelling regulation or became the focus of adverse consumer perception) will probably be undeliverable, in the short term, because of the dominance of GMM-based production methods. An 'alternative' policy of omitting such ingredients would also probably be impractical because technical production difficulties and loss of functionality in end products may arise;

- Imported ingredients derived from maize and oilseed rape and final food products containing them, have a higher probability of having been derived from GM crops than equivalent ingredients and products derived from EU origin raw materials. This probability is likely to increase over the next 1-3 years;

- Some operators in the EU food supply chain that operate a non-GM policy may be unaware that some ingredients and additives used (that they perceive are derived from non-GM materials) may be derived from GM materials. This is likely to be most common in respect of ingredients and additives derived from maize-based substrates, especially if imported from suppliers outside the EU.

Table 1: Non-GM ingredient policies: animal feed sector: example broiler feed & poultry meat production: availability and costs

Product	Ingredients affected	Availability of non-GM ingredients	Price differentials (non-GM having higher price) and cost implications
Broiler feed (policy: non GM protein & possibly non GM oils)	Soymeal Soy oil	Reasonable current but decreasing future availability.	Currently 2%-10% for meal, 13% for oil. Future rising to 8%-25% for soy meal and 25% for oil.
	Blended oils	Reasonable current & future availability.	Additional cost of avoiding soy oil is 3% to 13% (current and expectation for 1-3 years).
	Amino acids (lysine & threonine), some enzymes (phytase, beta-glucanase) and vitamins (B6 & B12)	High GMM dependence: lack of non-GM alternatives. Reasonable availability of NGM substrate (usually maize) if processed in EU. If finished ingredients imported, high probability of GM substrate use.	Supply availability problems the key constraint. Price not available but will be higher. Alternative 'ingredient avoidance' policy = reduced technical efficiency of feed and higher livestock production costs.
Poultry meat	As above	As above	*Currently +1.3% to +4.8% to feed cost and reduced profitability by -1.35% to -15%. Future +1.6% to +8.6% to feed costs and -13% to -29% on profitability.* Continued absorption of this cost by poultry sector unlikely – will have to pass cost on down supply chain. Avoidance of GMM ingredients not practical or deliverable in the short term.

Table 2: Non-GM ingredient policies: example product margarine: availability and costs

Product	Ingredients affected	Availability of non GM ingredients	Price differentials (NGM having higher price) and cost implications
Margarine (policy: Removal of all GM ingredients except perhaps those derived from GMMs).	Primary oil: soy replaced with sunflower or rapeseed.	Reasonable current & future availability.	Alternative oils trading at significant premium to GM soy oil (20% to 30% premium).
	Blended oils Emulsifier (mono & di-glycerides).	Reasonable current & future availability.	Additional cost of avoiding soy oil is 3% to 13% (current and expectation for 1-3 years' time).
	Anti oxidant (citric acid) Vitamins (E, B6 & B12), enzymes (lipases, phospho-lipases).	High GMM dependence: lack of non-GM alternatives. Reasonable availability of non-GM substrate (usually maize) if processed in EU. If finished ingredients imported, high probability of GM substrate use.	Supply availability problems the key constraint. Price not available but will be higher. ***Currently non-GM policy adds +16% to +18% to raw material costs. Similar cost expectations for the next 1-3 years.***

Table 3: Non-GM ingredient policies: example product chocolate based confectionery: availability and costs

Product	Ingredients affected	Availability of non-GM ingredients	Price differentials (NGM having higher price) & cost implications
Chocolate-based confectionery (policy: removal of all GM ingredients).	Blended oils	Reasonable current and future availability.	+3% to +13% to cost of ingredient.
	Maize flour	Reasonable current & future availability.	Low incorporation rate & small non-GM price premium = very small cost impact.
	Soy lecithin	Reasonable current but decreasing future availability.	Low incorporation & small non-GM price premium = very small impact on costs. ***Overall impact of NGM policy now and in next 1-3 years: adds +0.23% to +0.45% to raw material costs.***

Non-GM ingredient policy: overhead costs

In addition to the higher raw material costs that may arise from operating a non-GM ingredient policy (see above), other overhead costs will arise, dependent upon the size of the business and the complexity of its product and even customer portfolio. These costs include varying diversions of staff time (e.g. in purchasing, development and quality management, in particular) to a need to employ additional dedicated staff, to establish and maintain systems to deliver traceability and IP/segregation, and for testing. There are also likely to be periodic fees and associated internal management costs in using independent companies to undertake audits and verification of traceability and IP systems.

Operating costs may be adversely affected by reduced production capacity utilisation from having to shut down continuous manufacturing lines for cleaning, having to operate (and install) separate storage facilities, and possible reduced functionality of ingredients in products resulting in increased levels of wastage/spoilage or reduced product shelf life. In some cases, it is known that companies have chosen to use particular non-GM ingredients across their product range – and thus incur additional raw material costs – rather that operate segregated storage and production regimes. In others, it has been a cheaper option, overall, to continue with a more expensive raw material such as non-GM soya lecithin since the potential use of a non-GM alternative (e.g. ammonium phosphatide) only becomes feasible / acceptable if either replacement processing equipment is installed or resultant changes to the end product organoleptic properties are considered insignificant.

Overall costs directly attributable to a non-GM policy vary widely between businesses and are very difficult to quantify (especially as some of the traceability systems costs may now be considered as partially attributable to other trading requirements such as the EU General Food Law Regulation 178/2002).

Nevertheless, whilst the costs of switching raw materials away from GM origins to certified non-GM sources for some food products (see above) have been very small, the associated overhead cost of making, and maintaining, this policy is likely to have been significantly higher.

Concluding comments

To date, the direct costs of operating a non-GM ingredient policy have been limited (in terms of additional raw material costs) for many food products. The notable exception to this has been for products with high oil incorporation rates (e.g. cooking oils and margarine) where soy oil has been replaced with an alternative such as rapeseed oil. In addition, in the poultry meat production sector, the additional cost of using non-GM protein feed ingredients has had an adverse impact on profitability.

In the next 1-3 years, supply availability of non-GM material in the key soybean and derivative sector is likely to decline and the price differential between GM and non-GM material widen. This will make the continued absorption of additional non-GM related costs very difficult for any user sector with high levels of (non-GM) soybean/derivative usage because of the adverse impact on profitability. The outcome of this is likely to be one of the following:

- the additional cost is passed onto retailers and ultimately consumers in the form of higher prices of end products such as poultry meat. To date, consumers have rarely been given the option of a choice between GM and non-GM alternatives of the same product or faced price differentials between the two. A requirement to pass on the additional costs of supplying non-GM based soy products may lead to these choices being increasingly offered to consumers and it will be interesting to see consumer reaction when faced with these alternatives. Historic recording of general consumer buying patterns in such circumstances has tended to show that, in most cases, the cheaper alternative is chosen;

- retailers will re-examine their non-GM policies for these products (if they are unwilling to pass on additional costs of using non-GM materials in mainstream product ranges) and relax their policies on using non-GM derived products (e.g. widening tolerances / applying the requirement only to premium ranges rather than mainstream products);

- the additional costs are forced onto the supply chain upstream of the retailer. The likely consequence of this would probably be reduced output by some European producers of relevant products (notably in the livestock sector) rather than produce at a loss. In turn, this could result in shortages of non-GM derived (livestock) products for retailers, necessitating either a re-think about paying higher prices or increased reliance on non-EU imports, in which the probability of GM-based ingredients / derivatives is likely to be higher than in EU origin produce.

1. Introduction

EU Regulations 1829/2003[8] and 1830/2003[9], which have been applicable in the EU market since April 2004, together require the labelling and traceability of food and feeds containing Genetically Modified Organisms (GMOs) and products derived from them. These Regulations **extend the previous labelling requirements to all derivatives of GMOs, irrespective of the detectability of DNA or protein** resulting from the genetic modification in the final product. They also require transactions involving GMOs and products derived from GMOs to be documented and recorded for a period of five years ("traceability").

These comprehensive legal labelling and traceability requirements have implications for those businesses (suppliers, manufacturers and retailers) in the EU food and feed chain which have adopted "non-GM" or "GM-free" policies for their products. These businesses are having, or will have to re-examine these "GM avoidance" policies from both cost and feasibility perspectives against the combination of the wider legislation and the increasing global share of production of four major crops accounted for by GM cultivars.

Against this background, and at the request of some players in the EU food and feed supply chains, Agricultural Biotechnology in Europe (ABE) commissioned this independent research to examine further the feasibility and cost implications of maintaining these "GM avoidance" policies.

1.2 Objectives

The primary objective of the research was to provide a clear and concise examination of the potential problems and costs associated with maintaining a "non-GM" policy in the EU in a way that is easily communicable to European food and feed businesses.

Against this background, the main objectives were to:

- identify the origins and range of food and feed ingredients derived from GMOs that currently, or may in the near future, fall within the scope of the new labelling requirements (notably on clarification of the legal position of products derived from Genetically Modified Micro-organisms, "GMMs" and enzymes);
- examine and identify the levels of use of these ingredients in food and feed products sold in the EU;
- assess the feasibility and cost implications of maintaining a "non-GM" policy for products containing these ingredients.

In order to meet these objectives, the research was specifically targeted towards:

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[8] Regulation (EC) No 1829/2003 of the European Parliament and of the Council of 22 September 2003 on genetically modified food and feed: OJ L 268/1, 18.10.2003

[9] Regulation (EC) No 1830/2003 of the European Parliament and of the Council of 22 September 2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC

- identifying key products and ingredients which require to be labelled and for which difficulties in maintaining a "non-GM" policy may arise;

- identifying typical ingredient incorporation levels, current costs and potential costs of ensuring non-GM supplies. The specific examination of final products and costs was restricted to a short list of indicative materials (see section 5);

- examining current and likely future dynamics in the mainstream markets for soybeans and maize and how these will affect the baseline raw material costs of maintaining a non-GM policy.

1.3 Report structure and methodology

The report was based largely on desk research and analysis, supported by information from qualitative interviews with representatives of the EU food and feed chains, including retailers.

Following on from this introductory section, the report is structured as follows:

Section 2: background and general overview

Section 3: key products, ingredients and the level of demand for non-GM in the EU

Section 4: a forward look at the likely market dynamics over the next 1-3 years in the key commodity sectors (of soybeans, maize and oilseed rape)

Section 5: cost implications of delivering and maintaining a non-GM/GM avoidance policy in the food and feed chains.

2. Background and general overview

This section briefly considers the nature of GM avoidance policies adopted in the EU food and feed chains and how these have been affected by the 2004 EU labelling legislation. It is provided as a scene setting base to the subsequent discussion and analysis of market dynamics and cost implications.

2.1 GM avoidance policies

Under the pre-2004 labelling legislation, selective wording of publicly-stated, "non-GM" policies allowed a spectrum of "GM avoidance" to be in place.

Careful scrutiny of the policies was necessary to determine the extent of individual, commercial practices but, in practice, a "non-GM" policy could mean supplying products that had been selected / formulated to meet one or more of the following criteria by:

a) using, or changing to, ingredients from crops that have not been subjected to Genetic Modification:

   - removing ingredients which could have detectable presence of GM material (i.e. protein / DNA) above the (then) 1% threshold for adventitious "contamination" by re-formulation of food products away from (mostly) soy-based products and, to a lesser extent maize, to alternative crops for which no GM products or derivatives are currently allowed for growth / import into the EU;

b) procuring Identity-Preserved (IP), non-GM raw materials from non-GM crop supply chains:

   - primarily, this applied to soya but also to a lesser extent maize;

   - IP could be based on audited supplies and processes ("hard IP") or by sourcing the ingredients from geographic regions where GM crops were not being grown or likely to be imported / processed ("soft IP") *[see page5]*;

   - for the majority of ingredients, a 1% threshold for adventitious "contamination" applied although, in practice, many companies operated to 0.1% tolerance (considered to be the limit of quantifiable detection);

c) avoiding totally the use of <u>any</u> materials that have in some way been derived from gene technology (as per Austrian and German legislation);

d) supplying livestock products (e.g. fresh meat, eggs, milk) from animals that have been fed a diet free from GM derived protein ingredients;

   - the approach to non-protein elements, veterinary and prophylactic medicines remained ambivalent.

In relation to refined products such as soy oil where it is not possible to detect GM DNA/protein, policies fell into two categories. Some operators required suppliers to use non-GM derived raw materials (e.g. this policy applied to the use of soy oil in most food products used in some leading European retailer own-label foods like cooking oil or margarine).

In other cases, European retailers and food manufacturers continued to use certain ingredients obtained from GM crops or micro-organisms but did not label their presence because they were legally exempt from doing so:

- GM DNA/protein was no longer detectable after refining, e.g.
    - soy oil / lecithin;
    - vitamins and food acids derived from GM micro-organisms (GMMs)

- certain end-products (e.g. cheese) are legally exempt from declaring their components

- certain ingredients (processing aids, enzymes, carried-over additives).

Prior to April 2004, these approaches did not compromise a company's public "non-GM" policy, where this was given as a commitment to (or could be interpreted against) "the need to meet legal labelling requirements". However, the extent to which the average consumer is aware of, understands or accepts these distinctions is not known.

To date, where the introduction of these "GM avoidance" policies has resulted in additional costs being incurred in the supply chain (or, more importantly, resulted in losing the opportunity to use alternative, lower cost alternatives), this financial burden has largely fallen on the supply chain up to, but not including, the retail sector.

2.2 The new labelling regime

Since April 2004, companies in the supply chain wishing to operate "GM avoidance" policies have needed to accommodate significant changes to the legal definition of products that fall within the scope of labelling and traceability requirements as GM-derived products:

- a significant broadening of the range of products that are classified as "derived from GMOs" to include ingredients in which it is not possible to detect any GM DNA/protein:

    - in relation to soybeans and maize derivatives, the main additional products affected are the refined oils and starches / glucose syrups, respectively, but some 30 or so other food ingredients and additives can be identified as potentially having been derived from crops that have been genetically modified and are currently being grown commercially;

- identifying, on the label, the GM origin of any ingredient in a final product that is knowingly "derived from a GMO" regardless of the level of inclusion and the number of stages of refinement and / or chemical conversion the ingredient has undergone:

    - the legal exemptions from labelling certain ingredients (outlined above) remain in place but in the case of some soya derivatives these may now be subject to separate labelling requirements under new legislation on allergen labelling; the positions of processing aids and enzymes are currently subject to review by the Commission and are unlikely to be clarified until late-2005;

- tightening of the legal threshold to accommodate "adventitious presence" of GM-derived material from 1% to 0.9% coupled with a legal requirement to demonstrate that any GM presence (below 0.9%) was, indeed, "adventitious" (i.e. the operator must be able to show that appropriate steps were taken to minimize the chances of this presence occurring). In addition, a threshold of 0.5% applies to the adventitious presence of material from a GMO that has benefited from a favourable scientific Opinion within the Community:

    - these requirements apply even if the presence is not detectable by analysis, thus requiring comprehensive records to be in place throughout the supply chain and retained for a period of five years;

- extension of the labelling requirements to animal feed and petfoods.

Possibly recognising the very wide scope of the new legislation and potential international trade repercussions, an attempt was made (late in the drafting of the legislation) to distinguish between materials "produced from" and "produced with" GMOs[10] so that products considered to have been produced by fermentation and the use of related GM-derived "processing aids" would be exempt from the labelling requirement. However, this distinction was not formally introduced into the Articles of the Regulations and, consequently, the precise requirements related to the GM status of fermentation-derived materials remains legally unclear, despite the Commission and Standing Committee Expert Groups having published their views.

A meeting of the Standing Committee on the Food Chain and Animal Health in June[11] 2004 failed to agree but during a follow-up discussion in September 2004[12] a broad, but not unanimous, consensus was reached that food and feed (including ingredients such as additives, flavourings and vitamins) produced by fermentation using a GMM are:

- **outside** the scope of Regulation 1829/2003 if the GMM is NOT PRESENT in the final product (these materials are considered as having been produced with, rather than from the GMM.)

- **within** the scope of Regulation 1829/2003 if the GMM is PRESENT in the final product, whether "alive or not".

[10] Regulation 1829/2003, Recital 16: "This Regulation should cover food and feed produced 'from' a GMO but not food and feed 'with' a GMO. The determining criterion is whether or not material derived from the genetically modified source material is present in the food or in the feed. Processing aids which are only used during the food or feed production process are not covered by the definition of food or feed and, therefore, are not included in the scope of this Regulation. Nor are food and feed which are manufactured with the help of a genetically modified processing aid included in the scope of this Regulation. Thus, products obtained from animals fed with genetically modified feed or treated with genetically modified medicinal products will be subject neither to the authorisation requirements nor to the labelling requirements referred to in this Regulation."

[11] Standing Committee on the Food Chain and Animal Health (section on genetically modified food and feed and environmental risk): summary record of the 2nd meeting – 23rd June 2004

[12] Standing Committee on the Food Chain and Animal Health (section on genetically modified food and feed and environmental risk): summary record of the 3rd meeting – 24th September 2004

At the time of this Report (June 2005), the legal status of many fermentation products remains unclear and is not now likely to be clarified unambiguously until a review of the working of the legislation has been completed towards the end of 2005.

2.3 Implications of the labelling regime

2.3.1 Inconsistency between crop-derived and fermentation-derived products

A large number of common food and feed ingredients, additives and enzymes are produced directly or indirectly from GMMs, or using enzymes that have been derived from GMMs. The nature and complexity of these production routes are not widely recognised, nor is it widely appreciated that some apparently similar products may be treated differently under the current EU labelling regime depending on whether they are derived from plant or micro-organism / enzyme origins.

In particular, the requirement to identify positively, trace and label derivatives of GM crops, regardless of the number of stages of purification and/or subsequent chemical modification undertaken or the level of use, is inconsistent with the approach taken towards similar derivatives obtained from, or with the aid of, GMMs (or using enzymes derived from them).

Any operator wishing to avoid positive GM labelling of ingredients, additives and enzymes derived from crops that may have a GM origin will have to set up systems and records to ensure that only ingredients derived from non-GM origins are used. Similar requirements will apply to imports of finished products from third countries where raw materials derived from GM crops are widely used and, in particular, those countries where segregation of GM and non-GM materials is not widely practised. *[The crops of principal commercial interest, and which therefore comprise the focus of this research, are soya, maize, rapeseed and cotton. Very small quantities of other GM crops are grown locally but are of very limited significance in international trade.]*

In contrast, no such requirement for labelling currently applies to users of materials derived wholly or in part from a GMM, where no residues of the GMM remain.

The exemption from labelling of enzymes (which may contain proteinaceous materials derived from GMMs) that may remain in, but without effect on, the final product after processing is derived from other EU labelling legislation[13].

Notwithstanding legal exemptions from labelling of enzymes and other fermentation products, the question will remain as to whether the average consumer will consider the inclusion of such materials in products to be in accordance with a publicly-stated “non-GM” or “GM avoidance” policy and the level of “trust” that the consumer places in a given manufacturer / retailer.

2.3.2 Consequences

The extensive changes imposed by the legislation (regardless of the uncertainties and inconsistencies outlined above) mean that the requirement for labelling of crop-derived ingredients now extends to a far wider range of materials than previously, regardless of their level of use.

[13] Directive 2000/13/EC of the European Parliament and of the Council of 20th March 2000 on the approximation of the laws of the member states relating to the labelling, presentation and advertising of foodstuffs: OJ L109 p29 6.5.2000

In order to continue to apply "GM avoidance" policies, many businesses will therefore have to extend their ingredient / product procurement procedures to ensure that products (principally soy, maize and rapeseed, but also others depending on their geographical origin) comply with the new labelling threshold for non-GM products. The alternative will be to continue with existing supply arrangements and label products as GM-derived where it is not possible to establish otherwise.

In general, the incentive for any non-GM supplier or buyer to implement new measures to comply with the new legislation is directly influenced by the relative costs involved compared to the consequences of not complying (e.g. possible loss of non-GM price premia, or the inability to sell the supplies labelled as containing/derived from GMOs in a given (non-GM) market).

Where the consequences of exceeding the thresholds for adventitious GM presence or having to identify known GM ingredients are significant (e.g. either being unable to sell products to a supermarket that insists on a very tight tolerance as a condition of supply or consumers possibly switching away from products labelled to show that they contain GM ingredients), then suppliers are usually more prepared to make changes to their raw material procurement systems and incur the associated costs. Conversely, where the costs to a company of meeting the new labelling thresholds are significant but the economic consequences of labelling a product as GM are perceived to be limited (i.e. if it is perceived that customers will not insist on products being non-GM and/or switch to suppliers using only guaranteed non-GM supplies), the company is likely to withdraw from the "non-GM" market and revert to conventional origins for its products.

In addition, since the new legislation includes GM-derived products such as refined soy oil and maize starches and sugars (for which it is not possible to validate their origin by analytical tests for the presence of DNA / protein) these products are now in a similar position to organic products. Product integrity in the eyes of consumers will depend on the robustness and credibility of the traceability, authentication and certification procedures attached to the product.

Against this background, the greater the price differential between GM and non-GM derived products, the greater the incentive for unscrupulous traders to enter the market, trying to pass off GM-derived products as "non-GM". To some extent, this is bound to occur (as has happened in the organic sector) although it is difficult to predict the precise extent or its impact on product integrity in the eyes of consumers.

If this becomes a feature of the market, then one of the aims of the labelling legislation (to enhance consumer choice) will be undermined. In addition, legitimate traders of non-GM derived products may find their costs rising because of a need to take additional measures to maintain and demonstrate product integrity to consumers.

In addition, the availability of non-GM supplies of mainstream agricultural commodities like soybeans and maize has, does and will play an important role in influencing the ultimate cost of maintaining a "non-GM" policy. This is of particular relevance for livestock products where protein-based feed ingredients like soymeal account for significant shares of production costs (e.g. in poultry-meat and eggs).

The potential commercialisation / re-introduction of other GM crops, such as tomato, potato, rice and sugar beet (and more remotely, wheat and barley) – although likely to be outside the immediate timescale of this project and probably outside the EU – will further exacerbate the complexity of "GM avoidance" policies, particularly for those companies that trade internationally or are dependent upon internationally-sourced raw materials.

The net effect of the new labelling legislation will therefore be to make the delivery of "non-GM" policies more complicated, difficult and costly.

In the following sections, these costs and possible supply procurement issues, from both a current and near future perspective are examined.

3. The EU non-GM market: key products & ingredients

This section provides a baseline for subsequent analysis of cost implications for operating a GM avoidance policy. It covers the key crops and products of relevance and ingredients, additives and enzymes derived from them. It also provides an overview of the size and nature of the EU non-GM market.

3.1 Relevant crops and EU non-GM demand

3.1.1 Relevant crops/commodities

In 2004, the global planted area planted to GM crops was almost 78 million hectares (equal to seventeen times the total arable cropping area of the UK). Almost all of this global GM crop area derives from four crops, soybeans, corn, cotton and oilseed rape, with the GM crop plantings accounting for 26% of the global area planted to these crops. At the crop level, the GM share of global plantings was 51%, 12%, 24% and 15% respectively for soybeans, maize, cotton and oilseed rape.

3.1.2 GM share of global exports

Looking at the extent to which the leading GM producing countries are traders (exporters) of these crops and key derivatives (and therefore may be supplying markets in the EU), Table 4 and Table 5 show the following:

- ***Soybeans***: in 2004, 31% of global production was exported and 98% of this trade came from countries which grow GM soybeans. Assuming that the same proportion of production in these GM exporting countries that was GM in 2004 was also exported, then 60% of globally traded soybeans was GM. If, however, it is assumed that there is no active segregation of exported soybeans from these countries into GM versus non-GM product (i.e., exported soybeans are likely to comprise a mix of both GM and non-GM) then the GM share of global exports can reasonably be expected to have been 98% in 2004. As there has been some development of a GM versus non-GM soy market (mostly in the EU: see 3.1.4), which has necessitated some segregation of exports into GM versus non-GM supplies, the likely share of global trade accounted for by GM soybean exports is within the range of 60% and 98%. Based on estimates of the size of the non-GM soy markets in the EU and SE Asia (the main non-GM markets: see below for discussion of the EU market)[14], about 10% of global trade in soybeans is required to be certified as non-GM, and if it is assumed that this volume of soybeans traded is segregated from GM soybeans, then **the GM share of global trade is 90%**. **A similar pattern occurs in soymeal where about 72% of globally traded meal probably contains GM material**;

- ***Maize***: about 10% of global production was traded in 2004. Within the leading exporting nations, the GM maize growers of the US, Argentina, South Africa and Canada are important players (81% of global trade). Assuming that the proportion of production in these countries that was GM in 2004 is also exported, then 45% of globally traded maize was GM, although if it is assumed that there is no active segregation of exported maize from these countries into GM versus non-GM product (i.e. exported maize is likely to comprise a mix of

[14] Brookes (2004): The EU non-GM market size, features and size, GM crops and foods conference, Die Akadamie Fresenius, Koln, Germany (Nov 2004), and PG Economics (2003), Planning for the end of the moratorium; www.pgeconomics.co.uk

both GM and non-GM maize) then the GM share of global exports can reasonably be expected to have been 81% in 2004. As there has been some, limited development of a GM versus non-GM maize market (mostly in the EU, and to a lesser extent in Japan, which has necessitated some segregation of exports into GM versus non-GM supplies), **the likely share of global trade accounted for by GM maize exports is within the range of 45% and 81%, but closer to the higher end of this range**;

- ***Cotton***: in 2004/05, about 28% of global production was traded. Of the leading exporting nations, the GM cotton growing countries of the US and Australia are prominent exporters accounting for 44% of global trade. Based on the proportion of production in these countries that was GM in 2004, then 28% of globally traded cotton was GM, although if it is assumed that there is no active segregation of exported cotton from these countries into GM versus non-GM product (i.e. exported cotton is likely to comprise a mix of both GM and non-GM cotton) then the **GM share of global exports can reasonably be expected to have been 44% in 2004**[15]. **In terms of cottonseed meal, the GM share of global trade is about 27%**;

- ***Oilseed rape***: 12.5% of global oilseed rape production in 2004 was exported, with Canada being the main global trading country. The share of global oilseed rape exports accounted for by the two GM oilseed rape producing countries (Canada and the US) was 73% in 2004 (90% of this came from Canada). Based on the share of total production accounted for by GM production in each of the two countries, 55% of global oilseed rape trade in 2004 was GM. As there has been no significant development of a GM versus non-GM oilseed rape market (the highest level of non-GM demand is in the EU, which is largely self-sufficient and hence imports very little rapeseed), exports from Canada/US have not been segregated into GM and non-GM supplies and, hence, **the likely share of global trade accounted for by GM canola is probably nearer the 73% level of global trade** rather than the 54% level. **For rape meal, the GM share of global trade is about 51%.**

Table 4: Share of global crop trade accounted for by GM production 2004 (*million tonnes*)

	Soy beans	Maize	Cotton	Oilseed rape
Global production	189	740	25.6	43.9
Global trade (exports)	59.3	73.95	7.3	5.5
Share of global trade from GM producers	58.14	60.3	3.2	4.0
Share of global trade from GM producers if GM share of production used as proxy for share of exports	35.4	33.4	2.05	3.0
Estimated size of market requiring certified non-GM (in countries that have import requirements)	5.0	Less than 1.0	Negligible	Negligible
Estimated share of global trade that may contain GM (i.e., not required to be segregated)	53.14	59.3	3.2	4.0
Share of global trade that may be GM	90%	80%	44%	73%

Sources: USDA & Oil World statistics, PG Economics (2003), Brookes (2004)
Notes: Estimated size of non-GM market for soybeans in the EU 15%, and in Japan and South Korea 40%

[15] We consider this to be a reasonable assumption; we are not aware of any significant development of a non-GM versus GM cotton market and hence there is little evidence of any active segregation of exports from the US and Australia into these two possible streams of product.

Table 5: Share of global crop derivative (meal) trade accounted for by GM production 2004 (*million tonnes*)

	Soya meal	Cottonseed meal	Rape meal
Global production	135	15.7	21.15
Global trade (exports)	48	0.55	2.66
Share of global trade from GM producers	39	0.15	1.36
Share of global trade from GM producers if GM share of production used as proxy for share of exports	26.9	0.054	1.02
Estimated size of market requiring certified non-GM (in countries that have import requirements)	4.5	Negligible	Negligible
Estimated share of global trade that may contain GM (i.e. not required to be segregated)	34.5	0.15	1.36
Share of global trade that may be GM	72%	27%	51%

Sources: USDA & Oil World statistics, PG Economics (2003), Brookes (2004)
Notes: Estimated size of non GM market for soymeal in the EU 15%, and in Japan and South Korea 40%

3.1.3 EU-15 usage of these crops/commodities

Table 6 summarises the usage of the crops/commodities in the EU-15. Key points to note are:

- The vast majority of maize, oilseed rape and cotton seed used in the EU is derived from domestic EU production;

- Most soybeans and first stage derivatives used are derived from imports. As indicated above, the availability of import supplies of soybeans (and soymeal) come mostly from GM growing countries and this is confirmed through examination of the main origins of EU soybean and meal imports. In 2003-04, the main origin of EU-15 soybean imports were Brazil (63%), the US (22%), Paraguay (6%) and Argentina (5%). The main origins of soymeal imports were Argentina (50%) and Brazil (43%). All of these countries grew GM soybeans in 2004[16].

Table 6: EU-15 supply balance 2003-04 (*million tonnes*)

Product	Domestic production	Imports	Crush/Use	Exports
Soybeans	0.65	15.4	14.6	Negligible
Soymeal	11.51 (mostly from crush of imported beans)	21.67	31.15	2.04
Soy oil	2.67 (mostly from crush of imported beans)	Negligible	1.88	0.85
Rapeseed	11.77	0.32	8.89	0.14
Rape meal	5.15	0.41	5.5	0.05
Rape oil	3.72	0.01	3.52	0.19
Maize	39.56	2.5	39	0.5
Cotton seed	0.75	0.05	0.73	Negligible

Source: Oil World, Eurostat, EU Commission

[16] The respective share of total plantings in 2004 accounted for by GM soybeans were the US (85%), Brazil (23%), Argentina (98%), Paraguay (72%)

3.1.4 EU non-GM demand

A distinct non-GM market began to develop in the EU in 1998 (for ingredients used in human food) and was extended to the animal feed sector from about 2000. It focused largely on soybeans / soy derivatives and, to a much lesser extent, maize because these were the first two crops to receive import and use authorisations in the EU (before the introduction of the *de facto* moratorium).

Key features of the **soybean market** development have been (Table 7):

- *In the human food sector, a switch to using alternative non-GM derived ingredients (e.g. the replacement of soy oil with sunflower or rapeseed oil*). This was relatively easy for a number of food products like confectionery and ready meals where soy ingredient incorporation levels were low (e.g. 0.5 - 1%). This course of action has been more difficult to take in the animal feed sector because of the importance of soymeal as an ingredient in some feeds (e.g. broiler feeds, where typical incorporation rates are 20%-25%);

- *If the GM crop or derivative could not be readily replaced, non-GM derived sources of supply were sought*. This focused mainly on Brazil (but not exclusively) and involved the initiation of identity preserved (IP) or segregated supply lines to ensure non-GM derived supplies to customer-specific tolerances were available (traditional supply lines use commodity-based systems where there is broad mixing of seed in bulk for transportation);

- *GM derived crop ingredients have largely been removed from most products directly consumed (by humans)*. However, there are two major exceptions to this; soy oil derived from GM soybeans and ingredients derived from GM micro organisms manufactured using a soy derivative as a substrate (which continue to be widely used). In the animal feed sector, the demand for non-GM soymeal affects 12%-15% of the EU market. In the industrial user sectors, there is little or no development of the non-GM market[17] (i.e. the market is indifferent to the production origin of raw materials);

- *It has been reasonably easy for European buyers to identify and obtain supplies of non-GM derived soybeans and soymeal at 'competitive prices'*. The primary source has been Brazil, and mostly from the Northern half of the country. Where the adventitious presence threshold applied has been 1%[18] (for the presence of GM material), price differentials have tended to be in the range of 2% to 5% (i.e. non-GM soy has traded at a higher price than GM soy) over the last two years (the current price differential is about 4%-5%). When tighter thresholds and a stricter regime of testing, traceability and guarantees are required (e.g. to a threshold of 0.1%), the price differential has been within a range of 7%-10%;

- *the additional cost burden of supplying non-GM ingredients has largely been absorbed by the supply chain up to the point of retailers* (i.e. the cost burden has fallen on feed compounders, livestock producers and food manufacturers and has not been passed on to retailers and end consumers);

[17] This refers to all non food industrial uses and does refer to industrial uses where the raw materials are destined for human food use (e.g. maize starch used in food products)
[18] And more recently 0.9% in line with the new legal threshold

- *any price differential that has arisen has been mainly post farm gate*. At the farm level in countries where GM crops are widely grown, there has been and is currently very little development of a price differential. In Brazil (the focus of non-GM supplies of soybeans), there has, to 2004-05 been no evidence of a non-GM price differential having developed. In the US and Canada, the farm level price for non-GM supplies has tended to be within the range of 1%-3% higher than GM supplies, and this level of differential in favour of non-GM crops has had little positive effect on the supply of non-GM crops (i.e. GM plantings have continued to increase, with the price differential being widely perceived to be an inadequate incentive for most farmers to grow non-GM crops like soybeans.

Developments relating to the GM versus non-GM **maize market** have followed a similar path to the developments discussed above in relation to soybeans:

- *The food industry targeted removal of all GM-derived ingredients from products, including GM maize* or;

- *Non-GM derived sources of supply were sought*. This was relatively easy and focused on domestic EU origin sourcing, where the approval and commercial adoption of Bt maize has been very limited. The need to initiate identity preserved (IP) supply lines has also been limited because of the absence of GM maize material in the vast majority of EU supplies. Only in Spain (where 25,000 hectares of Bt maize were grown annually in the period 1998-2002 and 58,100 hectares were planted to GM Bt maize in 2004) has a (potential) need for greater attention to segregation / IP been relevant. Even here, there have been only limited problems, although some instances of contamination have been reported in neighbouring France. The majority of Bt maize grown in Spain is concentrated in a few regions and is supplied to the local animal feed compounding sector, where there is little demand for non-GM ingredients;

- *the demand for non-GM material is mostly found in the food sector (including starch*). However, these uses account for a minority of total EU maize use (about 23%), with the feed sector being the primary user of maize (75% of total use[19]). Overall, about 25%-29% of total demand for maize in the EU-15 is required to be non-GM;

- *as non-GM maize accounts for 96%-98% of EU maize supplies[20], the development of a clear GM and non-GM derived maize market has been less marked than in the market for soybeans and derivatives*. Where users of maize (notably in the food and starch sectors) have specifically required guaranteed non-GM maize (to the same thresholds as non-GM soy of mostly 1% and some to 0.1%), price differentials have tended to be in the range of 1% to 3% (i.e., non-GM maize prices have been higher than GM maize prices). These price differentials have been post farm-gate with no apparent price differential at the farm level;

- *the cost burden (where applicable) of using non-GM derived maize has generally been absorbed by the food chain*.

[19] The balance is accounted for by seed

[20] The GM share comes from Spanish production of about 0.32 million tonnes in 2003 and annual imports of between 0.6 and 1.4 million tonnes from Argentina

Table 7: Estimated GM versus non-GM soy and maize use 2003-04 in the EU (*million tonnes*)

Product	Market size	Non GM share	Non GM share (%)
Soy			
Whole beans	1.5	0.33	22
Oil	2.12	0.83	39
Meal	31.15	3.74-4.67	12-15
Total	***34.77***	***4.9-5.83***	***14-17***
Maize			
Food & starch	8.97	6.28	70
Feed	29.25	2.92-4.38	10-15
Seed	0.78	0.55	70
Total	***39***	***9.75-11.21***	***25-29***

Source: PG Economics, American Soybean Association, Oil World
Note: The range for the estimated share of non GM demand in the animal feed sector reflects the broad range of views and limited research in the sector

Overall, current EU requirements for non-GM ingredients of maize and soybeans (i.e. where buyers actively request that supplies are certified as being non-GM) accounts for about 14% to 17% of total soybean/derivative use and 25% to 29% of total maize use.

In respect of **other arable crops such as oilseed rape and cotton seed, there is no real GM versus non-GM market in the EU.** In the case of oilseed rape, no GM variety is currently approved/registered for commercial cultivation in the EU[21]. Hence, to date, all supplies of oilseed rape used for processing in the EU have been non-GM. In the case of cottonseed, the small usage market is similarly serviced by a combination of domestic non-GM supplies and/or imports from non-GM growing countries (notably Ivory Coast).

3.2 Food and feed ingredients, additives and enzymes derived from GMOs

This sub-section details the relevant food and feed ingredients, additives and enzymes obtained from GMOs that currently fall (or may in the near future fall) within the scope of "non-GM" policies (depending on possible further clarification of statutory labelling requirements for products derived from GM micro-organisms - "GMMs" - and likely consumer perceptions of such policies). It indicates the principal origins/sources of these materials, the sequential phases of extraction, purification and conversion that may take place during their production and typical supply chains for each material (or class of materials, where this is more appropriate).

Additional information on the origins and uses of emulsifiers, fatty acid and starch derivatives, preservatives, antioxidants and vitamins etc are provided in **Appendix 1**.

[21] It is, however interesting to note the ultra cautious behaviour of some crushers in the UK, where for crops supplied in 2004 (after the new labelling and traceability law became operational), farmers were required to make declarations as to the non-GM status of their oilseed rape crops, purely because of the (remote) possibility of GM adventitious presence arising from a GM oilseed rape farm scale trial.

3.2.1 General

For businesses sourcing raw materials and finished products solely from within the EU, the list of EU-approved crops is defined and includes cultivars / derivatives of all of the four main GM crops. However, not all globally-cultivated GM cultivars currently appear on the EU authorised lists and the adventitious presence of "non-approved" cultivars (and their derivatives) may either be not permitted or, if they have received a favourable scientific opinion from the relevant EU authorities, is subject to a labelling threshold of 0.5%.

If an individual food business is sourcing ingredients and/or finished products from third countries to the EU, then it must take the steps necessary to ensure that only EU-approved GM cultivars and / or their derivatives have been used to produce both the ingredients and / or finished products (and to label accordingly), or to obtain the raw materials from certified alternative "non-GM" sources (within the permitted labelling thresholds for GM adventitious presence)[22]. These precautions are necessary, not only where products are imported from countries where GM crops are grown but must also be applied to any materials sourced from countries where GM crops or their derivatives may have been imported, processed or used.

3.2.2 Soybeans

As indicated in section 3.1, considerable volumes of soybeans and derivatives (notably soymeal) are imported into the EU. In addition, numerous derivatives may potentially be present in finished products imported from third countries for direct consumption, albeit in many cases at low levels of inclusion in recipes and / or in small (relatively) traded volumes.

The following ingredients and additives are extracted directly or indirectly from soybeans or are obtained by further processing of soy derivatives in the presence of other food materials:

- Whole beans, sold in limited quantity in health food shops etc
- "Full fat", enzyme-active soy flour; about 42% protein, used as a bread improver in some bakery processes; essentially, milled whole beans (hulls may/may not be removed)
    - *use level: 0.2 – 0.5% of wheat flour in bread recipe (dependent on flour quality and type of wheat bread or roll)*
- Protein derivatives obtained / further extracted after the basic oil extraction process:
    - defatted flour/grits: ~52% protein, used as such or in textured form ("TVP" meat analogue or extender)
    - "concentrates": ~70% protein, used as such or in textured form
    - "isolates": ~90% protein
    - crude and refined protein products may be broken down by acid or enzymatic hydrolysis to produce a wide range of flavouring materials (HVPs), flavour enhancers and "hypo-allergenic" infant foods

[22] If the business is unable to establish conformity with either option, then it has no legal alternative but to discontinue the particular product.

  - soy sauce (produced by fermentation); cheap alternatives are blends of ingredients, largely based on HVPs which may be derived from a variety of plant origins or mixtures of plant proteins
  - soya "milk", tofu, miso, tempeh etc.
- Oils, separated by solvent extraction, refining, bleaching, deodorising etc:
  - sold as such by retail
  - used as ingredients (as pure oils) in processed foods
  - hydrogenated to varying degrees and / or subject to further modification by enzymatic or chemical means; used in a wide range of processed foods and as commercial frying fats
  - *[Use levels in foods range from 100%, through 80% - 40% (margarines and low-fat spreads) down to "traces" when oils are present as a result of previous use as a carrier for flavouring materials, anti-dust agents etc.]*
- Extracts derived from the crude oil refining process, such as
  - lecithin (refined to different degrees according to end-use)
    - lecithin may be fractionated / hydrolysed / enzymically modified for specific purposes
    - *[Use levels ~0.3 – 0.5% in chocolate, dairy and other "instantised" products, and all types of bakery products]*
  - tocopherols (used as anti-oxidants or as vitamin E precursors), either as natural extracts or subject to chemical modification (e.g. tocopherol succinate)
  - sterols, stanols and their esters ("phytosterols")
    - *increasing interest for their health benefits and use in "functional" foods; increasing number of foods authorised for their addition but daily intake restricted to 3 grams (originally by-products from tocopherols extraction)*
- Fatty acids are extracted and used as emulsifiers (E470 series). Examples include mono- and di-glycerides (E471), a range of glyceride esters (E472a-e series). Further details of the ranges of fatty acids and their esters are given in **Appendix I**, below.
- Isoflavones (health-benefit foods) are derived from the carbohydrate fraction removed during protein concentration
- Soya bran / hulls are a by-product from the initial extraction / cleaning stages (muesli etc)

Protein meal and speciality derivatives are used widely in animal feed.

3.2.3 Maize

Most maize is used in animal feed (see section 3.1). Food sector uses include the following but, when considering potential GM versus non-GM status, care must be taken to differentiate between the types of maize suitable for specific applications ("waxy", "dent", "flint") as their uses may not be interchangeable and not all varieties are commercially available as GM cultivars:

- Direct food use

   - on the cob, whole kernels (including canned),
   - flakes, grists and flours (brewery adjuncts, polenta), bread specialities such as multi-cereal breads, extruded/puffed snack-foods (including popcorn), tortillas, batter mixes, crumb coatings, carriers etc
   - pre-gelatinised flour in infant food and fine bakery wares
   - bran (breakfast cereals, carrier)
   - ruminant and poultry feed.

- Oils are used / sold in the pure, refined state; hydrogenated / partially-hydrogenated or subject to further modification by enzymatic or chemical means (use levels as per soya, above); maize germ oil (health food outlets)

- Extracts derived from the crude oils, such as

   - lecithin – limited quantities, not good quality, blended with Soy and Rape
   - sterols and stanols (from maize germ oil)

- Bran and fibres

   - isoflavones may also be derived from the bran

- Pressed maize cake is hydrolysed (using acid or enzymes) to produce flavouring materials, such as HVPs and flavour enhancers

- Starch and starch derivatives:

   - Maltodextrins, dextrins, modified starches (chemical and enzymic), glucose syrup, HFCS, dextrose – wide range of uses, including carriers / diluents for other food additives, encapsulants for flavours

   - Glucose syrup and dextrose are further processed to sugar alcohols and caramel (flavouring and colour additives). Further details of maize milling, starch and hydrolysis products are provided in Appendix 1.

Maize also provides the feedstock for a range of fermentation processes, which use any carbohydrate-rich fractions ranging from mashed grains (for grain alcohol) to refined sugar fractions and chemical products of these:

- Starch derivatives and sugar-rich fractions are substrates for the direct fermentation / enzyme-based conversion to manufacture the following, not specifically mentioned above:

   - Sorbitol, xylitol, mannitol, maltitol, erythritol
   - Trehalose, other "novel" sugar substitutes (needs further evaluation)
   - lactic acid and lactates (Na, Ca, K); citric acid and citrates;
   - gluconates, gluconic acid and glucono-delta-lactone
   - acetic acid
   - vitamin C (ascorbic acid), sodium ascorbate (anti-oxidant)
   - ethanol (a substrate for many synthetic chemical flavourings)
      - corn-based fermented drinks / spirits (e.g. Bourbon, some beer)
      - blended alcoholic beverages

    - food / carrier solvent uses

- lysine and threonine
- monosodium glutamate
- xanthan gum

[It must be noted that, although in many of these cases, the substrate may also be derived from non-maize origins, the GM issue remains because the micro-organisms and enzymes used have been derived by genetic modification.]

The lack of segregation of corn in North America results in difficulties with potential imports of products such as confectionery (glucose syrup) and finished cereal products from North America (limited volume/value).

In the case of grain alcohol production in the US, significant quantities of brewers' grain are used as animal feed ingredients and may be imported into the EU – currently subject to a pre-import certification process, arising from the Bt10 adventitious presence issue.

The uses of genetically modified micro-organisms (GMMs), and the enzymes derived from them, for some of these conversions are considered separately (**Appendix 1**).

3.2.4 Rapeseed

This is primarily of interest for the oil (including as a source of bio-fuel) and several specialist conversion products (for human consumption) and the residual meal (for animal feed):

- the oil is primarily used in salad oils, shortening, margarine, coffee whiteners, cakes and biscuits, breads and fried snacks. It is also used in some livestock rations, especially pig rations, both as an energy source and as a dust suppressant;

- an enzymically-modified rapeseed oil fraction provides the basis of a recently-approved EU Novel Food (Diacylglycerol, "Enova" Oil), a further example of a healthy ingredient for functional foods. The process involves esterification of the fatty acids in rapeseed (or soya) oils with glycerol or monoacylglycerol in the presence of an immobilised lipase;

- it can be a potential source of vegetable sterols obtained as a by-product of vitamin E extraction from the oil. The sterols are a complex mixture that is generally hydrogenated before use in yellow fat spreads (some sterols are also obtained from wood bark);

- it can be used as the basis of several speciality chemical emulsifiers for the baking industry such as mono-glycerides and DATEMS;

- it is the origin of the ammonium phosphatide emulsifier E442 used in chocolate;

- it may be used as an anti-dust agent on powdered products (0.05%).

3.2.5 Cotton

Cottonseed is processed into four major by-products: oil, meal, hulls and "linters". Only the oil and the linters are used in food products. Cottonseed oil / hydrogenated cottonseed oil are used, alone or in tailored blends, in a variety of foods including cooking fats, salad and frying oils (e.g. for snackfoods), mayonnaise, salad dressing, shortening, margarine and packaging oils.

Cottonseed meal is primarily used for animal feed.

Cotton linters are a source of refined cellulose and chemically-modified cellulose derivatives, E460 – E469 (Table 8), frequently referred to collectively as "cellulose gums", which are used as emulsifiers, stabilizers and thickeners in a range of foods such as meat and sausages, sauces and salad dressings, bakery products, tortillas and low-calorie products, and in high fibre dietary products as well as viscosity enhancers in ice cream. There is a thixotropic grade of micro-crystalline cellulose that performs in a manner very similar to Xanthan Gum.

Table 8: Cotton-based chemical derivatives

E460	Cellulose
E461	Methyl cellulose
E463	Hydroxypropyl cellulose
E464	Hydroxypropyl methyl cellulose
E465	Ethyl methyl cellulose
E466	Carboxy methyl cellulose Sodium carboxy methyl cellulose
E468	Crosslinked sodium carboxy methyl cellulose
E469	Enzymatically hydrolysed carboxy methyl cellulose

3.2.6 General use of vegetable oils/fatty acids

Fatty acids derived from a range of vegetable oils are reacted to produce a number of specialist emulsifiers for the baking, dairy and related industries.

Examples include mono- and diglycerides, DATEMS, Spans and Tweens. For a full list, see **Appendix 2**.

3.2.7 Enzymes

The European market for enzymes (for all applications; food, feed, detergent, textiles, pharmaceutical and technical application) is valued at about 0,6 billion Euros (about 30% of the 1.7 billion Euros world market). Enzymes for food and feed applications account for 40% to 50% (food) and 5% to 10% (feed) of total usage.

3.2.7.1 Enzymes used in food production

The second half of the 20th century has seen a significant growth in the use of enzymes in food processing. The main applications are:

a) Starch and sugar

In the early 19th century, it was found that glucose could be manufactured by boiling starch with acid. However, glucose imparts less sweetness than sucrose and this method of production has high-energy consumption. Therefore, over the past 30 years, the use of acid has been largely replaced by the use of different **starch-**

degrading enzymes (e.g. amylases) to convert starch to **glucose**. Today, enzymes are also used to convert glucose into **fructose**, the naturally occurring sweetener in honey and fruits, which is 40% sweeter than sugar. Fructose is widely used in soft drinks, confectionery, baked goods, ice cream, sauces, canned fruits and other products.

b) Dairy products

Cheese making is perhaps the first known production process involving enzymes. Today, enzymes have a variety of important applications in cheese and other dairy products. For centuries, rennet **(chymosin),** the milk clotting enzyme obtained from stomachs of calves, kid goats and lambs has been used in cheese making. However, calf rennet is relatively expensive and has now been substantially replaced with cheaper microbial chymosin obtained from genetically modified yeast. *[The enzyme is considered to be identical to traditional chymosin, and has the advantage of being acceptable for kosher and vegetarian foods.]* Microbial chymosin is used for about 70% of US cheese and 33% of cheese production world-wide.

Proteases and **lipases** also play a role in the cheese ripening process. An esterase-lipase enzyme produced in fungus is used as a flavour enhancer in certain cheeses.

A significant portion of the world's population (particularly in developing countries) cannot consume milk or milk products because of an intolerance to lactose or milk sugar. The enzyme **lactase** may be used to break down lactose, making dairy products more digestible to those with lactose intolerance.

c) Baked goods

Enzymes play a key role in baked goods. A key enzyme is **amylase** which breaks down the starch in flour to fermentable sugars, which in turn are transformed by the yeast into carbon dioxide (which makes bread rise). To ensure a uniform bread quality, amylase is added to flour before it is sold to bakeries. Amylase is also used as an important component in all "bread improvers" for all types of yeast-leavened baked goods.

Specific amylases (e.g. **maltogenic amylase**) have the effect of altering the structure of the starch in the bread so that the bread remains soft for a longer time. Parameters such as increased volume of the baked bread, more uniform crumb structure and increased tolerance towards variations in the baking process can be obtained by the addition of **xylanases (hemicellulases, pentosanases)**. Xylanase degrades some complex carbohydrates in flour (xylans, hemicellulose, and pentosans) into soluble fractions with high water absorption and helps formation of a homogeneous and flexible gluten network.

Amyloglucosidase can be used to ensure an even "browning" of the crust while use of **lipase** ensures an even crumb structure and increased volume.

Oxidative enzymes like **glucose oxidase** help create a dry surface of the dough resulting in better dough handling and increased volume. Furthermore, use of chemical oxidants may be eliminated or reduced.

Biscuits and crackers require flour with a relatively low protein level. Sodium bisulphite was traditionally used to reduce the protein but, being a non-specific reducing agent, it also reduces or eliminates vitamin B1 in the dough. The use of a **proteinase** enzyme has a more specific action against gluten protein while preserving vitamin content and making the use of the chemical superfluous.

d) Wine and juices

Enzymes improve the quality and stability of many juices. In apple juice, enzymes (e.g. **pectinases**) increase juice yield and improve the productivity of the pressing process. They reduce viscosity by enhancing the ability to filter and clarify the juices by degrading components of the cell wall such as pectins (a kind of "glue" binding plant cell walls together). Hence, they facilitate turning juice into concentrates for shipment and increase long-term stability. [Other fruits also contain pectin and specific **pectin-degrading enzymes** are used in the juice making process to reduce pectin content and improve clarity and prevent juice concentrates from jellifying].

Enzymes have always been involved in the wine-making process. The natural enzymes of wine yeast and grapes are responsible for the fermentation and play a role in maturing wine. Today, other microbial enzymes may be added to help sedimentation / maintain clarity and colour, and enhance aroma during the ageing process.

e) Brewing

The production of beer has always involved enzymes. Enzymes naturally present in barley malt break down the malt into substances like sugars (e.g. maltose) essential to the brewing process. Many brewers use microbial enzymes to control more precisely the brewing process by compensating for varying malt quality. **Beta-glucanase** is used to improve beer filtration, which can be blocked by gum-like substances (e.g. glucan) that are released from the malt during the brewing process. Various enzymes make possible the production of low carbohydrate, dry and low alcohol beers. *[Adding **papain** (non-GM plant) is still the most effective and least expensive way to prevent protein-based chill haze in beer, and thereby improving beer stability.]*

Origins of enzymes

Food enzymes can be obtained from different sources:

- Microorganisms like fungi (e.g. aspergillus sp.) and bacterium (e.g. bacillus sp.)
- Plants like papaya, pineapple, figs
- Animals like calf, goat (stomach), chicken (eggs)

Enzymes obtained from micro-organisms (microbial enzymes) dominate the enzyme market with enzymes obtained from animals playing a (decreasing) role in cheese-making. The market share of enzymes obtained from plants is low (< 5%) mainly because of their higher production costs. Proteases like papain, bromelain and β-amylase from barley are the most important plant-derived enzymes (n.b. non-GM).

Key enzymes used

The following enzymes are mostly used in food processing. Except where indicated, these may be derived from both **GMM and/or non-GMM** origins:

a) Starch degrading enzymes:
   - α- amylase
   - amyloglucosidase or glucoamylase
   - pullulanase
   - maltogenic amylase: <u>only</u> GMM
   - *β- amylase: only from non-GM-barley*

b) Non-starch-polysaccharide degrading enzymes;
    - xylanases (hemicellulases, pentosanases)
    - glucanases
    - pectin lyase and pectinesterase

c) Proteases: break down / modify proteins *(may also be derived from animals and non-GM-plants like papaya, pineapple and figs)*
d) Lipases: break down / modify fats and oils *(also from animals)*
e) Glucose isomerase: starch refining / fructose production
f) Lactase: breaks down lactose
g) Glucose oxidase: baking
h) Invertase (only from non-GMM)
i) Catalase
j) Inulinase
k) Lysozyme (*only from chicken egg*)

All commercially available enzymes and their application in foods are listed in Appendix 3 (including the production organism and, in the case of GMM, the donor organisms).

All microbial enzymes are extracellular metabolites. They are excreted into the fermentation medium and purified using several techniques (e.g. chromatography, filtration). It is in the utmost interest of each enzyme supplier that there are no DNA-containing residues (e.g. “dead” cells) in the commercial enzyme preparation because the strain of the used micro-organism is secret. *[Only enzymes obtained from plants or animals are extracted directly from the plant or animal cells.]*

There is no specific information available on the substrate used in the fermentation medium for each enzyme. The composition of the fermentation medium is considered confidential, being regarded as specific know-how for enzyme manufacturers. However, the use of different starch and glucose syrups derived from cereals, notably maize, and the use of soy-proteins is commonplace.

The **level of use** varies between 5 and 500 mg/kg or mg/l application substrate. Nearly all enzymes are used in a free state, only glucose isomerase for the production of fructose syrup is used in a bound stage (bound to an inert substance for continuous production).

The **costs** for enzymes also vary considerably. Commodity enzymes like amylases and xylanases cost between 3 and 25 €/kg (α- amylase: 3 – 25 €/kg depending from enzyme concentration and application; xylanases: 5–10 €/kg, optimal level of use: 100 – 200 mg/kg). Innovative enzymes like phospholipase and maltogenic amlylase (both obtained from GMM) are more expensive (100-150 €). Enzymes for specific applications (e.g. hypo-allergenic infant formulations or flavourings) may cost up to several thousand euros.

Legal aspects
The legislation controlling the use of enzymes in food processing is not fully harmonized in the EU. Enzymes used for food processing are considered to be either food “additives” or “processing aids” according the definitions in the “Council Directive 89/107/EEC concerning food additives authorised for use in foodstuffs intended for human consumption”.

Food additives are essentially substances that are added to food and have a technological function in that food, while processing aids are substances that are added during food processing for technical reasons (e.g. amylases for starch hydrolysis) and may end up in the food but do not have a technological function in the final food. Depending on the application in food, one and the same enzyme can either be used as a processing aid or as an additive.

Currently, only two enzymes (lysozyme and invertase, both non-GM-derived) are considered as additives and permitted according to the Council Directive. They have to be labelled in the list of ingredients.

All other enzymes are currently exempted from this Directive because they are considered as processing aids. Therefore they do not currently have to be labelled or fall under the legislation relating to GMO labelling. However, a proposed new Enzyme Directive is currently being considered, which would result in most enzymes falling under the legal definition of "additives" and hence included within labelling provisions. This development would have important implications for food manufacturers, dependent on the use of enzymes obtained from GMMs, and who currently operate GM avoidance policies.

3.2.7.2 Enzymes used in animal feed production

There has been increased use of enzymes to improve feed over the last ten years. Enzymes are incorporated into feedingstuffs to enhance digestion inside the animal's gut. Their effects are complementary to those of enzymes contained in the feeding stuffs raw materials or produced by the animal and its digestive microflora. They are used to help break down antinutritional factors (e.g. non-starch polysaccharides in cereals, e.g. glucan) and/or increase the availability of essential components of the diet, thus resulting in:

- Better utilisation of feed ingredients
- Increased productivity, reduction of costs
- Increased flexibility in the design of the diet
- Reduction of waste, lessening of the environmental burden.

The main applications of enzymes in feed are:

- **Phytase:** increases the availability of phosphate in the diet, making the addition of mineral phosphate unnecessary and leading to a substantial reduction (up to 30%) of the amount of phosphate in the manure
- **β-glucanase** in a barley-rich diet causes partial break down of the barley β–glucan, thereby enhancing the efficiency of fat, protein and starch digestibility
- **Xylanase** in wheat-based diets causes partial break down of (arabino) xylan, a non-starch polysaccharide, thereby enhancing the efficiency of fat, protein and starch digestibility
- **α- Galactosidase** is used in feed rich in vegetable proteins (e.g. soybeans). These legumes also contain oligo-saccharides, which cannot be degraded by the animals' own enzymes. The oligo-saccharides are fermented in the large intestine with a loss of energy. The galactosidase digests this substances in the small intestine and thereby reduces this loss of energy
- **α-Amylase** reduces the viscosity of starch rich feed material in liquid feeding systems and further facilitates the digestion of starch
- **Proteases** facilitate the digestion of proteins.

Feed enzymes can be obtained from different sources:

a) Microorganisms like fungi (e.g. Aspergillus sp.) and bacterium (e.g. Bacillus sp.)
b) *[Plants like papaya, pineapple and figs].*

Enzymes obtained from microorganisms (microbial enzymes) dominate the feed enzyme market with the market share of enzymes obtained from plants very low (and decreasing due to their higher production costs). *[Proteases like papain and bromelain are the most important plant-derived enzymes and are non-GM].*

The following enzymes are mostly used:

- non-starch-polysaccharide-degrading enzymes
- xylanases (hemicellulases, pentosanases): non-GMM and GMM
- glucanases: non-GMM and GMM
- cellulase: non-GMM and GMM
- phytase: only from GMM
- α-galactosidase: mainly from GMM
- protease: non-GMM and GMM (*and from non-GM-plants like papaya, pineapple and figs)*
- α–amylase: non-GMM and GMM

All commercial available enzymes and their application in feed are listed in Appendix 3 (including the production organism and donor organisms).

There are no data available on the market share of these enzymes obtained from GMMs. Enzymes derived from GMMs do however, play an important role in feed (e.g. phytase).

All microbial feed enzymes are extracellular metabolites. As with enzymes used in food products, the enzymes and substrates used are highly confidential to each manufacturer.

The level of use varies between 5 and 500 mg/kg or mg/l application substrate. Nearly all enzymes are used in a free state (powdered or liquid preparations).

Feed enzymes have been considered as feed additives within the EU since 1993. There are several key Directives, which control the approval procedures, the safety, use and labelling of all additives in feed including feed enzymes, irrespective if the enzyme is produced by GMM or not. In respect of labelling requirements enzymes fall within the relevant Directives on genetically modified feed.

4. Sourcing non-GM: the future

This section examines possible future developments in markets for the main crops/commodities for which GM traits are widely available and used. It focuses mostly on the market for soybeans and derivatives, where the GM versus non-GM market differentiation has been most marked. The other main arable crops grown and used in the EU, for GM crops that are currently widely grown on a global perspective are then considered (i.e. maize and oilseed rape).

4.1 Soybeans and its main derivatives

How the markets for GM versus non-GM derived soybeans/derivatives will develop is essentially determined by how the balance of supply and demand of each category of product develops.

4.1.1 The current balance of supply and demand

At present, the level of demand for non-GM soybeans/derivatives is significantly below the available supply. Global demand for non-GM soy is probably about 10-12 million tonnes of bean equivalents. Global supply has been and is, currently significantly above this volume; looking at Brazil alone, the primary source of non-GM soybeans and derivatives, total exports of soybeans and soymeal were respectively in 2003/04 23.4 million tonnes and 14.7 million tonnes. GM soybeans accounted for 23% of total production in Brazil in 2004, mostly located in the Southern most states. Thus if it was assumed that about 50% of the Brazilian crop (that grows roughly North of Sao Paulo) is not subject to any co-mingling with the GM soybeans (i.e. crops grown in the Northern half of the country are unlikely to be mixed with crops from the South where the GM crops are concentrated), and then about 25 million tonnes of (non-GM) soybeans were probably available in the Northern half of the country. Whilst a significant proportion of this crop may be used domestically, this represents a fairly large supply base from which the global demand for non-GM soybeans can be met. Thus **global demand has been relatively easily serviced by available supplies from Brazil alone**. In this circumstance, it is not surprising that **the price differential for GM versus non-GM soybeans/derivatives has been fairly small.**

The analysis below explores the likely future direction of prices for GM versus non-GM soybeans and derivatives, based on probable changes to future supply of the two types of product (the analysis assumes that demand for non-GM material remains at current levels).

4.1.2 Future supply

This is the crucial factor of influence affecting both the future availability and price of non-GM soybeans and derivatives relative to GM supplies.

Our analysis of current non-GM supply availability, trends in plantings to GM versus non-GM soybeans (globally and, more specifically, in Brazil) and the approvals process for growing GM soybeans in Brazil, suggests that **the availability of non-GM soybeans from Brazil is likely to fall substantially in the next 1-3 years, and that the price differential between GM and non-GM soybeans (and derivatives) is set to widen significantly**. More specifically:

- *The Brazilian government has now formally approved the planting of GM soybeans*. This will facilitate the further multiplication and allow the marketing of seed suitable for growing in Brazilian conditions containing the GM herbicide tolerant trait, rather than farmers using imported (smuggled) seed from Argentina. The net effect of this legalisation process will be to make the planting of GM soybeans additionally attractive to more Brazilian soybean farmers. It also has the potential to extend the planting of GM soybean cultivars into more northerly Brazilian regions, once the technology is available in soybean varieties suitable for growing in Northern regions[23];

- *Given the lack of farm level price premia for non-GM soybeans* and the popularity of GM, glyphosate-tolerant soybeans (because of the farm cost savings obtained) amongst soybean farmers in the US, Canada, Argentina, Paraguay, Uruguay and (more importantly), in Brazil (where over 20% of the 2004 crop has been planted with illegally imported seed), it is highly probable that **the availability of non-GM derived soybeans/derivatives from Brazil will fall significantly in the next 1-3 years**. Table 9 summarises the farm level impact of using GM soybeans in Brazil relative to non-GM soybeans. This shows that **the farm level benefit of growing GM HT soybeans is between \$29/ha and \$71/ha**. In terms of benefit per tonne of output, this is equal to between \$12/tonne and \$31/tonne. Thus, **in order to keep the average Brazilian soybean farmer growing non-GM varieties, it is likely to require the payment of a price premium (relative to GM soybeans) of between 4.2% and 10.5%.** This level of price premium would therefore have to be added to the existing post farm price differential for non-GM soybeans, suggesting that the potential price differential for non-GM soybeans relative to GM soybeans from Brazil will have increased (from 2% to 5%) for soft IP soybeans to 8% to 20%, and for hard IP soybeans (from 7%-10%) to 13% to 25%;

Table 9: Farm level economic impact of growing GM soybeans in Brazil 2004 (\$/ha)

	Non-GM soybeans	GM herbicide tolerant soybeans
Variable costs of production		
Seed	35	50
Fertiliser	77.5	77.5
Herbicides	62-94	17-27
Other crop protection	68	68
Machinery operation	42	40.5
Other variable costs	64.6	57.5
Total variable costs	*349.1-381.1*	*310.5-320.5*
Difference		***28.6-70.6***
Difference per tonne		***12.5-30.8***

Sources: based on data from the Department of Agriculture in Parana
Notes: Average yield (2.29 tonnes/ha) based on 2004, price \$210/tonne ex-farm (based on 2004)

[23] A number of varieties suitable for growing in the Central and Northern regions of Brazil containing GM herbicide tolerant technology are already available for planting in 2005/06

- Any increase in the share of the Brazilian soybean crop accounted for by GM cultivars, especially into more northerly regions, will increase the chances of co-mingling of GM and non-GM crops, especially in the post farm transport, storage and processing sectors. As a result, this will probably lead to a greater number of buyers of non-GM derived material having to initiate more stringent controls on supplies to minimise the chances of GM adventitious presence occurring. The net effect of such a move will be an **increased use of 'hard IP' and less use of 'soft IP' systems**. As indicated above, this in turn, will add further to the cost of sourcing non-GM soybeans (and derivatives) relative to the price of the GM derived alternative;

- **GM herbicide tolerant technology is a cost reducing technology**. As such, the medium to long term effect of widespread use of this technology in soybeans on a global basis should contribute towards reducing the real, world price of soybeans and derivatives. This is clearly difficult to quantify. Two pieces of research have attempted to measure this effect. Moschini (2001) estimated that world soybean prices were 0.5%-1% lower in 2000 than they would have been in the absence of the technology and work by Qaim & Traxler (2002) estimated that the impact of GM HT soybean adoption on global soybean prices had been –1.96% by 2001. What this suggests is that the increasing adoption of GM HT technology in global soybean production (accounting for over half of global production in 2004) has probably already contributed to reducing the real price of globally traded soybeans and that, as global adoption levels continue to increase, this effect will become greater, adding further to the differential between GM and non-GM soybean prices[24].

4.2 Maize and oilseed rape

4.2.1 The current balance of supply and demand

As with the markets for GM versus non-GM derived soybeans/derivatives, how the respective markets for maize and oilseed rape will develop will be determined by how the balance of supply and demand of each category of product changes.

The development of distinct markets for GM versus non-GM maize and oilseed rape has been much less marked in the EU than the market for soybeans, due largely to the virtual self sufficient nature of the EU markets for maize and oilseed rape (as distinct from soybeans / derivatives, which are much more dependent on imports):

a) ***Oilseed rape*****:** to date no GM variety is currently approved/registered for commercial cultivation in the EU, although the oil from several varieties of GM Rape has been approved for food use under Regulation 258/97 and rapeseed products for animal feed under Directive 90/220 (Directive 2001/18). As a result, **all oilseed rape and derivative products produced in the EU have effectively been non-GM**. This abundance of non-GM raw material has also played a role in facilitating some switching of food product ingredients away from GM soybeans/derivatives and into rapeseed-based ingredients. The only 'incidence' where a GM versus non-GM ingredient issue has arisen to date

[24] As the technology is cost reducing, the higher price paid for non-GM soybeans is not a true price premium. Those who wish to buy non-GM soybeans are paying a higher price because they are foregoing the opportunity to pay less for their soybeans rather than having to pay more for them

relates to the importation of some confectionery products that may have used highly refined food ingredients such as the emulsifier ammonium phosphatide derived from oilseed rape grown in North America, and where the lack of segregation has resulted in the supplier being unable to give assurances as to the non-GM status of the feedstock.

b) ***Maize***: as indicated in section 3.1 above, the vast majority of EU maize / derivative consumption is derived from EU origin maize, of which 99.4% was non-GM in 2004. As such, **sourcing non-GM maize has not been difficult** and possible concern about GM adventitious presence being found in non-GM maize supplies has largely been confined to some parts of Spain, where GM maize has been grown, and neighbouring areas of France. Here, the GM maize has largely been sold for use into the animal feed sector and those users requiring certified non-GM maize (mostly the food using sector, including the starch sector) have not experienced difficulties in sourcing non-GM material. Price differentials, where they have arisen, have only been between 1% and 3% (in favour of non-GM maize).

   In respect of maize imports, of the 2.5 million tonnes of maize that the EU annually imports, the majority of this has been for use in the feed industry (mostly in Spain and Portugal) where there has been no requirement for certified non-GM material. As such, a significant proportion (e.g. about 60% in 2003) of these imports has probably been of GM maize from Argentina. The primary category of maize imports which has had a certified non-GM requirement has been in respect of flint maize (mostly imported from Argentina) used in the manufacture of breakfast cereals. As GM traits have not been available in this specialist maize, accessing non-GM flint maize has also not been a problem.

   It is possible, that some (a very small number) food and drink products imported into the EU may contain or are derived from GM maize (e.g. bourbon imported from the US). In the case of confectionery containing glucose syrup, as with rape derivatives above, the absence of adequate assurances on GM segregation has largely precluded imports into the EU.

   Lastly, the EU animal feed sector annually uses 5-7 million tonnes of imported maize gluten (a by-product of starch manufacturing). These imports are almost all sourced from the US and hence are likely to be derived from GM maize (or from non-GM maize that has been mixed with GM maize prior to processing). To date, the use of this GM-derived ingredient in animal feed has not led to any significant development of a GM versus non-GM maize gluten market because the main livestock product sectors in which a demand for non-GM derived protein feed ingredients has developed (fresh poultry and eggs) do not traditionally use maize gluten in rations[25].

   More recently, the occurrence of contamination of US maize with Bt10 has highlighted the direct use of ground maize as a feedstock for alcohol production and the use of the spent grains as animal feed imports to the EU. Although the volumes are believed to be small, the EU has introduced a positive release, certification system for this product.

[25] The main feed user sector of maize gluten is the dairy sector. Demand for use non-GM derived protein ingredients in the dairy feed sector has been very small and hence any move away from the use of maize gluten as a feed ingredient because of its probable GM origins has also been minimal

4.2.2 Future supply

Our analysis of current non-GM supply availability, trends in plantings to GM versus non-GM oilseed rape and maize (globally and separately in the EU) and the approvals process for growing GM maize and oilseed rape in the EU, suggests the following:

a) Oilseed rape

The EU is currently in the process of considering further approvals for the importation, processing and use of selected GM oilseed rape varieties and their derivatives. Import availability of GM oilseed rape is therefore likely to increase in the next few months. Looking at the availability of supplies of oilseed rape on global markets, this is currently dominated by GM origin products (between a half and three-quarters: see section 3). Nevertheless, non-GM supplies have been available in reasonable volumes from countries such as Australia (1.2 million tonnes in 2003/04). **In the next 1-3 years, this relative balance of GM versus non-GM supplies on global markets is unlikely to alter significantly**, mainly because Australia has introduced an effective moratorium on planting of GM oilseed rape, which is likely to last to at least 2008. Looking forward to a five year time horizon (2010+), there is reasonable expectation that additional countries such as Australia may approve the planting of GM oilseed rape. Once this occurs, sourcing of non-GM oilseed rape on global markets will be come more difficult, unless buyers will be willing to pay sufficient price premia in order to more than 'offset' the gains farmers obtain from growing GM oilseed rape[26].

In relation to possible cultivation of GM oilseed rape in the EU, **we do not foresee any commercial plantings of GM oilseed rape in the EU during the next 3 years**, mainly because GM oilseed rape is perceived to be a crop with possible co-existence problems (related to the issue of volunteers in subsequent crops).

b) Maize

Currently, the EU allows the importation and use of several types of GM maize and its derivatives. In the next 2-3 years, it is expected that additional import approvals will be forthcoming (e.g. approval of maize containing resistance to Corn Rootworm). In addition, there is likely to be continued expansion of the global area planted to GM maize, further increasing the share of globally traded maize (and derivatives) accounted for by GM cultivars. The net effect these expected trends will be increased availability of GM maize/derivatives and decreased availability of non-GM maize/derivatives. **Those wishing to procure and use non-GM maize and derivatives are likely to find limited, additional difficulty in accessing certified non-GM sources of supply.** The differential between GM and non-GM maize prices traded on global markets may increase but will probably continue to remain fairly small (up to 5%).

Domestically, the EU has already approved the planting of GM Bt maize. Over the next 2-3 years, plantings of this maize are likely to see modest increases from the 2004 baseline (58,100 ha in Spain), as additional plantings occur in Spain, and some small scale plantings occur in other EU member states, as national / regional level co-existence arrangements are finalised. However, **by 2008, the vast majority of EU maize is still likely to be non-GM, and therefore accessing supplies of certified non-GM maize and derivatives from within the EU is not likely to be problematic**.

[26] In Canada, the financial benefit for growers of GM canola in 2004 was about US$32/tonne relative to conventional canola. Assuming this represents the minimum price premium that would have to be paid to most farmers to grow non-GM, this equates to a price differential of about 15%. Inclusive of the additional post-farm costs of segregation etc, this suggests a price differential of about 20% would be required to secure access to significant and consistent supplies of non-GM oilseed rape.

Price differentials between GM and non-GM maize/derivatives may increase marginally (reflecting an increased need to check the non-GM status and to ensure segregation) but can be expected to remain no higher than 3% to 4%.

5. Non-GM policies: cost implications

This section builds on the analysis presented in section 4 by examining, for a range of food products, the current and likely future costs of maintaining a non-GM ingredient policy. This has been undertaken by assessing the costs of key ingredients according to whether a non-GM policy is applicable or not (i.e. comparing ingredient/raw material costs for a GM versus non-GM derived product). Where relevant (e.g. where soy or maize-based ingredients are used), *an additional forward looking (2-3 years) assessment of costs* is also provided.

The products have been selected to represent a range of applications where GMO avoidance policies are in place. They include products where GM ingredients represent both a significant proportion of total ingredient use, products where re-formulation of ingredients used (as distinct from switching to a non-GM equivalent of the same crop) has occurred and livestock-based products where GM ingredients are important components of feed. The products use recipes that may be regarded as typical of the sector concerned:

a) Fresh poultry meat
b) Soy oil and onward conversion to margarine
c) Flour-based baked product: synthetic “cream”-filled, coated biscuit
d) Chocolate-based confectionery product: similar to above, with typical chocolate coating
e) Pizza: “deep pan” base with ham and mushroom topping
f) Prepared ready-meal: chicken breast with bacon, savoury stuffing and sauce

5.1 Fresh poultry meat

As indicated in section 4, the fresh poultry meat sector has been the main livestock product market in the EU where a market for animals reared on a partial non-GM diet (focusing on protein-based ingredients and to a lesser extent, oil-based ingredients) has developed.

The impact of this policy, its possible extension to additional feed ingredients and likely developments in the next 1-3 years are examined further in the sub-sections below.

5.1.1 A typical broiler ration

A breakdown of a typical broiler feed ration is presented in Table 10. In relation to the GM versus non-GM ingredient issue, a number of ingredients are, or could be derived from GM origins (inclusive of GMMs):

- *Soymeal*: this is the second most important ingredient used in broiler rations and the primary source of protein used[27]. It is the ingredient that has been the focus of attention where the GM versus non-GM status of feed ingredients has been an issue. It accounts for just over 22% of the total cost of the feed ingredients used in broiler rations;

[27] Soymeal is the preferred source of protein in poultry rations from both a technical and value for money basis

- *Soy oil and blended oils* (that may contain soy oil): these account for about 11% of total feed ingredient costs. Currently, there are some broiler feeds that are required to use certified non-GM soy oil (to the EU labelling threshold of 0.9%), although the majority of feeds are probably currently using 'any origin soy oil', and hence are labelled as containing GM origin soy oil. Where blended oils are used, these come mostly from a mix of a number of oils that may include soy oil. If buyer requirements stipulate that non-GM oils are to be used, one alternative practice is to replace blended oils with additional use of IP soy oil;

- *Lysine and threonine*: these amino acid supplements account for nearly 3.9% of total ingredient costs. All current conventionally produced broilers in the EU probably use GM derived lysine and threonine, with no feeds having a non-GM origin requirement (other than organic, where the use of synthetic amino acids is not permitted);

- Certain *enzymes* and *vitamins*: these may account for over 6% of total feed ingredient costs. Most of the enzymes (e.g. beta glucanase, phytase) and some vitamins (e.g. B2 and B12) used are derived from GMMs. Almost all current conventionally produced broilers in the EU do not have a requirement to use certified non-GM derived enzymes or vitamin ingredients (other than organic, where enzymes are not usually used and vitamin use is more limited than in conventional production).

Table 10: Typical broiler ration (per tonne of feed)

Ingredient	Incorporation %	Typical price (€/tonne)	Ingredient cost (€)	Current status: GM versus non-GM
Wheat	61.5	92	56.58	Non-GM
Cooked rapeseed / pulses mix	6.75	226	15.26	Non-GM
Highpro Soya meal	20	195	39.00	GM or Non-GM
Fishmeal	3.5	576	20.16	Non-GM
Soy oil	1.5	426	6.39	GM or Non-GM
Blended oils	3.5	375	13.12	GM or Non-GM
Lysine	0.38	1,503	5.71	GM
Methionine	0.26	1,897	4.93	Non-GM
Threonine	0.04	2,773	1.11	GM
Enzymes	0.05	4,816	2.41	GM or Non-GM
Vitamins & trace elements	0.5	1,750	8.75	GM or Non-GM
Other ingredients (e.g. salt, limestone, sodium bicarbonate, monocal)	2.0		2.59	Non-GM
Total cost of raw materials			***176.01***	

Note: Prices quoted are for Spring, 2005, typical EU values (e.g. CIF Rotterdam). All prices are based on no preference between GM and non-GM origins (i.e. selection of ingredients based solely on technical and economic factors)

5.1.2 GM and non-GM feed ingredient availability and costs

For these ingredients for which GM derived material may be used, Table 11 summarises the current prices and/or availability of non-GM alternatives. Key points to note are:

a) For mainstream ‘commodity-based’ ingredients such as soymeal and soy oil, non-GM alternatives are available and are being used. The impact on the cost of feed, both currently and over the next 1-3 years, is shown in Table 12. This shows that **the application of a non-GM policy in respect of all protein and oil ingredient use is currently adding between 1.03% and 4.8% to the cost of feed raw materials. Over the next 1-3 years this is likely to rise and add an extra 5.8% and 9.6% to feed raw material costs**.

b) **For a number of minor ingredients, comprising some synthetic amino acids, vitamins and enzymes, where GM derived ingredients currently**

dominate usage, switching to a non-GM alternative is less straightforward and hence is/would be more difficult to achieve (especially in the short term):

- For some ingredients such as threonine, there is no current non-GM source of supply. For some others (e.g. lysine) the non-GM supplies available are very limited. This means that any significant expansion in non-GM demand could not be met in the short term. As such, it is not possible to provide a price/cost estimate for supplying a non-GM alternative;

- In the absence of a direct non-GM alternative for some ingredients, the main way to avoid GM ingredients would be to omit the (GM) ingredient and / or to aim to compensate with increased use of other ingredients (e.g. using more fishmeal in the diet to compensate for not using GM lysine). Taking such action (as occurs in the provision of organic feed) has two main effects; it raises the cost of feed and delivers a technically inferior feed (which delivers poorer feed conversion). The effect of these changes is a net increase in the cost of production for the livestock producer. For example, a typical conventionally produced broiler would use about 1.63 kgs of feed (price about €207/tonne) per kg of broiler (live weight), compared to 4.25 kgs of feed (€405/tonne) for an organically produced broiler.

Table 11: Broiler feed ingredients: GM versus non-GM alternatives

Ingredient	Non-GM availability	Price differential (non-GM being higher priced)
Soymeal	Reasonable current availability but expect reduced availability from 2006 (see section 4). Ability to forward contract supplies several months already decreasing in 2005 relative to 2004.	Currently 2%-5% (soft IP), 7%-10% (hard IP). 2006 onwards widening differential to 8%-20% (soft IP), 13%-25% (hard IP).
Soy oil	Reasonable current availability but expect reduced availability from 2006 (see section 4).	Currently 13%. 2006 onwards possibly widening to 25%.
Lysine	There is only one known source of non-GM derived lysine production globally (South Africa), accounting for no more than 1.5% of global lysine production. The vast majority of globally produced lysine is derived from GM fermentation production methods. The only broiler producing sector that does not use lysine (or other amino acids) is the organic sector. Organic broiler feeds seek to compensate through higher incorporation rates of other meals with higher amino acid profiles (e.g. fishmeal). These alternative practices do, however come with technical constraints (e.g. additional use of fishmeal is limited by the need to avoid the end product 'tasting of fish').	The current minute availability of non-GM lysine suggests that any significant move in the EU for requiring amino acids used in poultry feeds to be derived from non-GM sources could not be supplied. Even if the South African plant could increase production from its existing production capacity, it is doubtful if any such increase could be significant (the plant is reported to be small in comparison to the mainstream production facilities operated using GM fermentation techniques). Prices of non-GM lysine could therefore be subject to possible substantial short term increases. In a longer term scenario of possible significant and sustained demand for non-GM lysine, prices would probably fall back as new production capacity came on line. However, lysine produced from non-GM fermentation methods is more expensive to produce and therefore its price would inevitably trade at a premium to GM derived sources. The short term alternative to using lysine in feed would be to switch to additional incorporation of other meals with higher amino acid profiles like fishmeal, which would increase the cost of raw materials.
Threonine	There are no current production facilities in the world for threonine using non-GM production methods.	It is possible that non-GM production could be set up, if there was sufficient demand. However, this possible expansion in production is dependent on new capital investment, which itself, will only be forthcoming if potential investors can see a genuine, long term future market for non-GM threonine. In the short term, there are no GM alternatives available, other than omission (as in organic rations). The price of any non-GM threonine would be higher than GM derived material because GM fermentation methods are considered to be the most cost effective production method.
Vitamins	The main vitamins of relevance from a GM versus non-GM perspective are B2 and B12 because the vast	The current limited availability of non-GM vitamins suggests that any significant move in the EU for requiring vitamins used in poultry feeds to be derived from non-GM

	majority of global available supplies are derived from GM fermentation production methods. Chemically synthesised vitamin B2 (and possibly B12) using non-GM methods has limited availability.	sources could not be supplied in the short term. It is possible that existing non-GM production plants could expand production and/or new entrants to this non-GM market might occur, if there was sufficient demand. However, this possible expansion in production is probably dependent on a combination of new capital investment and/or an adequate price incentive (given that non-GM production is more expensive than GM-based production). The prices of non-GM vitamins are likely to increase in the short term, especially if food grade (more expensive) products have to be used (it is difficult to estimate by how much prices might rise because this is also demand dependent – food grade possibly trades at 30% premium to feed grade). In a longer term scenario of significant and sustained demand for non-GM vitamins, prices would probably fall back as new production capacity came on line. However, as vitamins produced from non-GM fermentation methods are more expensive to produce (even in China, which is probably the lowest cost source of supply), prices would inevitably trade at a premium to GM derived sources.
Enzymes	The main enzymes used in broiler feeds of probable relevance to the GM versus non-GM issue are phytase, beta-glucanase and xylanase. The majority of these are produced from GM fermentation techniques (see appendix 3).	The possible impact is the same as discussed above for vitamins, lysine and threonine.

Table 12: Impact of using non-GM soy-derived ingredients: broiler ration (€/tonne of feed)

Ingredient	Baseline cost (can use GM ingredients)	Additional cost of using non-GM ingredient: current	Additional cost in 1-3 years time
Soymeal	39	+0.78 to +3.9	+3.12 to +9.75
Soy oil	6.39	+0.825	+1.6
Blended oils	13.12	+3.71	+5.52
Total of these ingredients	58.51	+5.31 to +8.435	+10.24 to +16.87
Total ingredient cost	176.01	+5.31 to +8.435	+10.24 to +16.87
% change in cost of feed raw materials		***+1.03 to +4.8***	***+5.8 to +9.6***

Notes:

1. Soymeal: lower end of range is based on soft IP systems and upper end of range is based on hard IP systems, operating to a GM adventitious presence threshold lower than 0.9%. Premia in 1-3 years time, see section 4
2. Soy oil: assumption for non-GM premia in 1-3 years time based on a range of the current 20% premia to 25% (in line with the expected non-GM soybean premia)
3. Blended oils: assumed to contain soy oil originally resulting in a switch to additional use of certified non-GM soy oil

5.1.3 Non-GM policy: implications

a) Protein and oil feed ingredients

The implications of the changes relating to maintaining or extending a non-GM protein and oil feed ingredient policy for the broiler production sector are significant (Table 13):

- **Currently, the impact of being required to use only certified non-GM protein ingredients is reducing gross margin profitability by between 1.35% and 6.8%. If the requirement of customers is to also use only certified non-GM oils in feed this could reduce gross margin profitability by between 9% and 15%;**

- **Over the next 1-3 years, the negative impact on broiler profitability of being required to use non-GM protein and oil feed ingredients is set to increase. A non-GM protein only requirement will potentially reduce margins by 13% and a non-GM protein and oil policy could cut margins by over 29%.**

This analysis illustrates why, in recent years, the small levels of additional costs associated with operating to a non-GM protein only ingredient policy[28] have largely been absorbed by the broiler producing sector. However, extending this policy to include using certified non-GM oils[29] would reduce current profitability more significantly and would be unlikely to be sustainable unless buyers of broiler meat in the European retail sector are prepared to pay premia for the non-GM-derived meat. In addition, **maintaining a non-GM protein requirement only is also likely to be unsustainable over the next 1-3 years unless European retail buyers of broiler meat are prepared to pay premia for the non-GM derived meat, sufficient to offset the expected increases in the cost of non-GM soy-based feed ingredients**.

Table 13: Impact of paying premia for non-GM soymeal on poultry production margins

	Current position (scenario 1)	Current position (scenario 2)	Future (1-3 years: scenario 1)	Future (1-3 years: scenario 2)
Impact of non-GM premia on feed cost/tonne	**+0.4% to +1.98%**	**+2.7% to +4.3%**	**+1.6% to +4.95%**	**+3.9% to +8.6%**
Impact on poultry producer gross margin	**-1.35% to -6.8%**	**-9% to -15%**	**-13%**	**-29%**

Source: based on broiler production data: UK (Nix Pocketbook 2005)
Notes/assumptions:

a) Current position **scenario 1** = the most common current non-GM requirement based on only non-GM protein must be used, **scenario 2** = non-GM protein and oils must also be non-GM. The low end of the range assumes a soft IP system is used and a 0.9% GM adventitious presence threshold is used, whilst the high end of the range assumes a hard IP system is used and a GM adventitious presence threshold of less than 0.9% is used (aiming for 0.1%).
b) Baseline feed cost €207/tonne purchased from a compounder which operates on an assumed margin of about 5%.
c) Variable costs used to calculate gross margin = feed, heat, lighting and cost of chick. Excludes labour and housing costs. Feed accounts for 81% of total variable costs in baseline.
d) Baseline farm gross margin is €0.33/bird on a sales price of €2.05/bird.
e) The reader should note that the margins and feed costs presented are based on a broiler producer buying in feed from a feed compounding business. The figures are therefore indicative of the impact of operating a non-GM policy for protein and oil ingredients. For some broiler producers the impact is likely to be less marked (likely to be the large scale integrated poultry meat producers who manufacture their own feed) and for some others the impact may be greater.

b) Other ingredients in feed

In respect of **other feed ingredients such as amino acids, vitamins and enzymes, any non-GM policy that extends to these ingredients will be faced with practicality and feasibility difficulties** before any consideration of cost implications. Whilst it is technically possible to substitute or omit some of these ingredients from broiler rations (as occurs in the organic sector):

- The limited current availability of some non-GM alternatives would be inadequate to service the requirements of the European market in the short term (if a significant part of this market were to require the use of certified non-GM ingredients);

[28] Operating to a 0.9% GM adventitious presence threshold
[29] Based on current profitability and non-GM soy oil premia

- Use of feed with omitted ingredients, or the use of ingredients that 'partially substitute' for the technical attributes contained in synthetic amino acids, vitamins and enzymes, is likely to result in poorer feed conversion rates and hence additional costs of production (to add to those referred to above in respect of protein and oil-based ingredients).

In sum, an extension of any non-GM policy in respect of feed ingredients such as amino acids, vitamins and enzymes is probably not deliverable in the short term. In the medium to longer term, it is technically possible but would come with additional costs.

5.2 Soy oil and use in margarine

Soy oil use in food products such as margarine has been a sector in which there have been significant movements away from the use of GM derived raw materials.

The impact of this policy and likely developments in the next 1-3 years are discussed further in the sub-sections below.

5.2.1 Margarine raw material use

A breakdown of a typical spreadable margarine product is presented in Table 14. In relation to the GM versus non-GM ingredient issue, a number of ingredients are, or could be derived from GM origins (inclusive of GMMs):

- Sunflower oil is the main ingredient used (about 56% of total raw material costs). The choice of sunflower as the main ingredient has been influenced by a policy to substitute soy oil (which may be GM-derived) in favour of a guaranteed non-GM raw material;

- Blended oils (excluding soy oil), which account for about 31% of total ingredient costs. The blended oils used may be a mix of a number of oils such as rapeseed, sunflower and palm oil. As with the use of sunflower oil, the products used may be required to be guaranteed as coming from non-GM origins;

- Of the minor ingredients, the emulsifiers (mono and di-glycerides of fatty acids), some preservatives (e.g. citric acid), some vitamins (e.g. E, B6 and B12) and enzymes (e.g. lipases) may be derived from GM origins (either from the use of GMM and/or the substrate used in the fermentation stage of their manufacture).

Table 14: Typical branded margarine (main) ingredient composition (59% vegetable fat spread/ per tonne equivalent)

Ingredient	Approximate incorporation %	Ingredient Cost (€)	Current status: GM versus non-GM
Sunflower oil	36	201	Non-GM (formerly often based on soy oil but switched out of soy oil in late 1990s)
Vegetable oil (blend)	24	114	Non-GM (a blend of oils such as rapeseed, sunflower and palm oils, excluding soy oil, unless certified non-GM)
Buttermilk powder	2	41	Non-GM
Emulsifier (mono- & diglycerides)	1	1.7	GM or Non-GM
Preservatives / antioxidants	0.3	2.9	GM or Non-GM
Vitamins, enzymes	Trace	Minute	GM or Non-GM
Salt	1.4	1.42	Non-GM
Total cost of raw materials		***362.02***	

Note: The balance of ingredient weight is largely made up of water, Vitamin content (e.g. tocopherol 20 micrograms per 100 kgs, vitamin B6 and B12, respectively 5 micrograms per 100 grams), preservatives and antioxidants (e.g. citric acid, potassium sorbate).

5.2.3 Non GM ingredients availability/costs

For the ingredients for which GM-derived material may be used, **Error! Reference source not found.** summarises the current prices and/or availability of non-GM alternatives. Key points to note are:

- For the main oil-based ingredients (sunflower oil and blended oils), non-GM origin products are widely used. The impact on the cost of margarine raw materials, both currently and over the next 1-3 years, is shown in Table 16. This shows that **the application of a non-GM policy in respect of all non-GMM ingredients is currently adding over 16% to the cost of raw materials**. It is interesting to note that when most food manufacturers first switched away from the use of soy oil to alternatives like sunflower and rapeseed oil (late 1990s), these oils traded at a discount to soy oil, and hence the switch of ingredients involved to no material change to the cost of raw materials. Maintenance of this raw material policy stance has, since 2000, been adding significantly to raw material costs of margarine manufacturers in the EU. **Over the next 1-3 years this position is unlikely to change** with the premia being paid for using sunflower and rapeseed oils rather than GM-derived soy oil remaining at least at current levels.

- **For the minor ingredients**, comprising mono & di-glycerides, citric acid and some vitamins, it is likely that the primary substrate used in their manufacture is non-GM (mostly maize, and/or possibly rapeseed or soybeans if manufactured in the EU). **Ensuring that these substrates are non-GM has not been problematic and any additional cost involved has been negligible in terms of total ingredient costs. Over the next 1-3 years, no significant changes to the availability or price effect of using these ingredients are expected**.

The exception to this would occur if products derived from GMMs become required to be positively labelled in the EU and food manufacturers decide the extend their non-GM ingredient policies to include GMMs (enzymes like lipases or phospholipases). Under this scenario, supply availability is likely to be a significant problem in the 1-3 year time period, although in the longer term a switch to non-GMM-based products may be possible, if manufacturers of relevant products (citric acid, vitamins B6 and B12) perceive that there is likely to be sustained and consistent demand for non-GMM derived produce so that they may be willing to invest in the necessary production capacity to deliver such products. The cost of such ingredients would probably be higher than current GMM-derived material (the lack of a current market for such products makes it difficult to estimates prices), although in the context of total margarine raw material costs, such additional cost would be negligible.

Table 15: Branded margarine ingredients: GM versus non-GM alternatives

Ingredient	Non-GM availability	Price differential (non-GM being higher priced)
Sunflower oil (substitute for soy oil)	The use of sunflower oil (or rapeseed oil) has been significantly influenced by margarine manufacturer policies to avoid labelling products as containing GM derived ingredients and hence there has been a switch away from the use of soy oil, into sunflower (and rapeseed) oil. There is abundant availability of non-GM sunflower oil, given the lack of GM developments in this crop. Accessing sources of supply of non-GM rapeseed oil has also not been a problem given the almost self sufficient nature of the EU market in rapeseed and derivatives (see section 3). Reasonable current availability of supplies of non-GM origin oils from both crops can be expected in the next 1-3 years	Currently both sunflower and rapeseed oils trade at a significant premia in the market compared to GM-derived soy oil (31% premia for sunflower oil and 21% for rapeseed oil). The price differential between GM derived soy oil and certified non-GM soy oil is about 13% (it therefore trades at a discount to rapeseed oil). For the next 1-3 years, projections for the prices of baseline oil prices vary (e.g. the USDA forecast up to a 10% decrease in global soy oil prices, the OECD forecast a 5% increase in world oil prices, and the FAPRI model analysis[30] products a 3% decrease in world oil prices). Against this background of uncertainty and potential market volatility, the differentials between soy oil and sunflower / rapeseed are likely to be maintained, mainly because of expected strong demand for oils. The non-GM soy oil price differential, relative to GM derived soy oil, is however expected to widen from 13% to possibly 25%.
Blended vegetable oils	There has been good availability of blended oils from oilseeds that are not derived from GM crops (rapeseed, sunflower and palm). Reasonable availability can also be expected over the next 1-3 years (see above).	The price of blended vegetable oils clearly varies according to the mix of oils used. The cheapest available oils are currently palm oil and soy oil (GM derived) and hence blends with high shares of these oils tend to trade at lower prices than blends with higher shares of higher priced sunflower and rapeseed oil. Current price differentials between blended oils made from non-GM sourced oils and blends that may include GM derived soy oil (and / or GM derived rapeseed or cottonseed oil) fall within a range of about 3% to 13%. As indicated above, the future price of oils is subject to uncertainty. Future differentials can be expected to at least be the same as current levels
Emulsifiers (mono- and diglycerides)	Derived from glycerines, which in turn are derived from hydrogenated soy oil (or maize oil). Currently, there is reasonable availability of certified non-GM soy oil or maize oil: see section 3) from which these emulsifiers are manufactured, and most emulsifiers used in the EU food sector are probably derived from certified non-GM soy or maize oil origins	The very low incorporation levels for emulsifiers in margarine means that the use of certified non-GM hydrogenated soy oil as the base substrate for manufacture has a negligible impact on the raw material costs of production for margarine (accounts for less than €2 (about 0.5%) to the total cost of raw materials used). Any future widening of the GM versus non-GM soy oil price differential (as expected in the next 1-3 years) will have only a minute impact on the raw

[30] See European Commission 'Prospects for agricultural markets & income 2004-2011 for the EU 25'. www.eu.int/comm/agriculture/publi/index

	Over the next 1-3 years availability of certified non-GM soy oil is expected to fall, although availability of non-GM maize in Europe is likely to remain reasonably easy to access	material costs of margarine production
Antioxidants (citric acid)	A fermentation product that uses glucose as it main energy substrate. The most common raw material is maize. Abundant availability of certified non-GM maize in the EU both currently and expected in the next 1-3 years. If imported from countries outside the EU, likelihood of GM maize having been the origin is much higher (this likelihood can be expected to increase in the next 1-3 years). The manufacturing process uses GMMs	Price of non-GM maize typically trades at the same price or a small premia to maize not provided with certified non-GM origin status. The very low incorporation levels (0.3%) means that the use of certified non-GM maize as the base energy substrate has a negligible impact on the raw material costs of production for margarine (accounts for less than €3 (about 0.8%) to the total cost of raw materials used. Price of non-GM maize in Europe unlikely to alter significantly in the next 1-3 years. Any move to require labelling of GMMs and an active policy taken up by food manufacturers to avoid such labelling will require a move away from current manufacturing methods. For the time period of 1-3 years, any such move is likely to result in a lack of available supplies of non-GMM derived citric acid. In the longer term, supplies might become available if manufacturers perceive this to be a consistent and longer term based demand and make the necessary investment in non-GMM-based production facilities. It is not possible to estimate the price implications for this hypothetical scenario, although at the end product level (margarine), even a substantial increase in the price of citric acid based on not using GMMs (e.g. a doubling in price) would have a very small impact on the total cost of raw materials
Vitamins (E, B6 & B12)	Vitamin E is extracted from the oils of crops like soybeans, maize and rapeseed. Current and future availability of non-GM origin oils is reasonable. Vitamin B6 and B12 are fermentation products (using GMMs), and typically derived from a glucose energy-based substrate derived from maize. For availability see antioxidants above	The very low incorporation rates for all vitamins means that the impact of using a certified non-GM origin substrate (even if price premia for the base oil were to rise substantially) has a negligible impact on the total cost of margarine raw materials. Any possible future requirement to avoid using GMMs in the manufacture of vitamins B6 and B12 would probably result in short/medium term problems of supply availability (see antioxidants above)

Current price differentials (Spring 2005): sunflower oil €557/tonne, rapeseed oil €517/tonne, GM derived soy oil €426/tonne (all CIF Rotterdam prices). The certified non GM soy oil price is about €480/tonne

Table 16: Impact of using non-GM derived ingredients: branded margarine (€/tonne of margarine)

Ingredient	Baseline cost (can use GM ingredients)	Additional cost of using non-GM ingredient: current	Additional cost in 1-3 years time
Sunflower oil	153 (GM derived soy oil)	+48	+48
Blended vegetable oil	111	+3 to +7	+3 to +7
Total of these ingredients	**264**	**+51 to +55**	**+51 to +55**
Other raw materials with possible GM origins: mono- & diglycerides, citric acid, enzymes and vitamins E, B6 & B12)	4.62	+0.14	0.14 (but supply availability problems if non-GMM products required)
Other raw materials (e.g. buttermilk, salt)	42	Not applicable	
Total raw material costs	*310.62*	*+51.14 to +55.14*	*+51.14 to +55.14*
% change in cost of margarine raw materials		***+16.5 to +17.7***	***+16.5 to +17.7***

Notes:

1. Sunflower oil: baseline alternative uses GM derived soy oil
2. Blended oils based on a mix of oils from rapeseed, soybeans, sunflower and palm
3. Current price differentials between the different oils are assumed to continue in 1-3 years. Based on forecasts of future projected prices this is probably a conservative assumption

5.3 A cream-filled chocolate-flavoured biscuit

As indicated in section 3, most food product manufacturers have actively moved away from the use of GM-derived ingredients since the late 1990s. The impact of this policy in respect of a typical chocolate cream biscuit product (and likely developments in the next 1-3 years) is examined further below.

5.3.1 Raw material use

A limited number of ingredients used in this type of biscuit are, or could be derived from GM origins (inclusive of GMMs: Table 17). Blended vegetable oils (excluding soy oil) are the main ingredient of relevance, accounting for about 32% of total ingredient costs. The blended oils used may be a mix of a number of oils such as rapeseed, sunflower and palm oil and commonly, the products used are required to be certified as from non-GM origins. Of the other minor ingredients, the full fat soy flour and the ammonium caramel colouring may be derived from GM origins (the latter product may be derived from maize or sugar).

Table 17: Typical chocolate cream biscuit ingredient composition (per tonne equivalent)

Ingredient	Approximate incorporation %	Cost of ingredient (€)	Current status: GM versus non-GM
Wheat flour	40	154	Non-GM
Vegetable oil (blend)	20	95	Non-GM (a blend of oils such as rapeseed, sunflower and palm oils, excluding soy oil, unless certified non-GM)
Cocoa powder	3	18.75	Non-GM
Sugar syrup	1.5	9.6	Non-GM
Ammonia caramel colour	2	20.01	GM or Non-GM
Full fat soy flour	0.25	0.86	GM or Non-GM (Non-GM usually a requirement)
Other ingredients (raising agents, salt)	1.75	1.55	Non-GM
Total cost of raw materials		***299.86***	

5.3.2 Non GM ingredients: availability/costs

For the ingredients for which GM derived material may be used, Table 18 summarises the current prices and/or availability of non-GM alternatives and

Table 19 illustrates to broad cost of using certified non-GM ingredients:

- the main ingredient base is derived from products (wheat and sugar) for which GM technology is currently not available (and/or is not expected to be available commercially in the next three years) and hence there has been no requirement to actively change raw material procurement procedures;

- **The ingredients that may be derived from GM soy or maize (vegetable oil blends, full fat soy flour and possibly ammonium caramel colouring) account for only a small share of total ingredient use and cost. The additional cost of using only certified non-GM ingredients has probably added only 1.1% to 2.2% to total raw material costs**;

- **Over the next 1-3 years, the additional cost of using only certified non-GM ingredients is likely to remain fairly insignificant (at about 1.1% to 2.3%).**

Table 18: Chocolate cream biscuit ingredients: GM versus non-GM alternatives

Ingredient	Non-GM availability	Price differential (non-GM being higher priced)
Blended vegetable oils	There has been good availability of blended oils from oilseeds that are not derived from GM crops (rapeseed, sunflower and palm). Reasonable availability can also be expected over the next 1-3 years (see above).	The price of blended vegetable oils clearly varies according to the mix of oils used. The cheapest available oils are currently palm oil and soy oil (GM derived) and hence blends with high shares of these oils tend to trade at lower prices than blends with higher shares of higher priced sunflower and rapeseed oil. Current price differentials between blended oils made from non-GM sourced oils and blends that may include GM derived soy oil (and/or GM derived rapeseed or cottonseed oil) fall within a range of about 3% to 13%. As indicated above, the future price of oils is subject to uncertainty. Future differentials can be expected to at least be the same as current levels.
Full fat soy flour	Currently, reasonable availability of certified non-GM soybeans from which full fat soy is derived. Over the next 1-3 years availability of certified non-GM soy is expected to fall.	The low incorporation level for full fat soy flour means that the use of certified non-GM soybeans as the base material has a limited impact on the total raw material costs of production. It accounts for about €0.86 (0.3%) to the total cost of raw materials used, with the requirement to use certified non-GM soy having added €0.04 to the cost). Although the price differential between non-GM and GM soybeans is likely widen significantly in the next 1-3 years (see section 4), the small share of total ingredient use and cost accounted for by full fat soy flour means that there will be only a marginal increase in overall raw material costs (rising to about €0.98 compared to €0.82 if GM derived soy were to be used).
Ammonia caramel colouring	Derived from sugar or hydrolysed maize starch. Abundant availability of certified non-GM maize in the EU both currently and expected in the next 1-3 years. All sugar beet supplies globally are non-GM and are expected to remain so in the next 1-3 years.	Price of non-GM maize typically trades at the same price or a small premium to maize not provided with certified non-GM origin status. The very low incorporation level (~2%) means that the use of certified non-GM maize as the base substrate has a very small impact on the raw material costs of production (if a certified non-GM maize is used and this trades at a 3% price premium relative any origin maize, this would potentially add only €0.58 (0.2%) to the total cost of raw materials. As the price of non-GM maize in Europe is unlikely to alter significantly in the next 1-3 years, no change to this level of cost impact is expected.

Current price differentials (Spring 2005): sunflower oil €557/tonne, rapeseed oil €517/tonne, GM derived soy oil €426/tonne (all CIF Rotterdam prices). The certified non-GM soy oil price is about €480/tonne.

Table 19: Impact of using non-GM derived ingredients: chocolate cream biscuit (€/tonne of biscuit)

Ingredient	Baseline cost (can use GM ingredients)	Additional cost of using non-GM ingredient: current	Additional cost in 1-3 years time
Blended vegetable oil	92.6	+2.5 to +6	+2.5 to +6
Full fat soy flour	0.82	+0.04	+0.164
Ammonia caramel colouring	19.5	+0.58	+0.58
Total of these ingredients	112.92	+3.12 to +6.62	+3.24 to +6.744
Other raw materials (e.g. butter milk, salt)	182.75	Not applicable	Not applicable
Total raw material costs	295.67	+3.12 to +6.62	+3.24 to +6.744
% change in cost of raw materials		***+1.1 to +2.2***	***+1.1 to +2.3***

Notes:

1. Blended oils based on a mix of oils from rapeseed, soybeans, sunflower and palm
2. Current price differentials between the different oils are assumed to continue in 1-3 years. Based on forecasts of future projected prices this is probably a conservative assumption
3. Non GM maize used as base material for caramel colouring assumed to trade at a 3% price premia relative to any origin maize both currently and in 1-3 years time

5.4 Chocolate-based confectionery (coated biscuit)

5.4.1 Raw material use

The ingredients used in this category of product that are, or could be derived from GM origins (inclusive of GMMs) are summarised in Table 20. Blended vegetable oils (excluding soy oil) are the main ingredient of relevance, accounting for about 5% of total ingredient costs. The blended oils used may be a mix of a number of oils such as rapeseed, sunflower and palm oil and commonly, the products used are required to be certified as from non-GM origins. Of the other minor ingredients, the maize flour and the soy lecithin may be derived from GM origins.

Table 20: Example chocolate-based confectionery (biscuit) ingredient composition (per tonne equivalent)

Ingredient	Approximate incorporation %	Cost of ingredient (€)	Current status: GM versus non-GM
Milk chocolate	32	681.6	Non-GM
Sugar	21	134.4	Non-GM
Wheat flour	25	160	Non-GM
Vegetable oil	12	57	Non-GM (a blend of oils such as rapeseed, sunflower and palm oils, excluding soy oil, unless certified non-GM)
Maize flour	5	14.3	GM or Non-GM (non-GM usually a requirement)
Sugar syrup	1.5	9.6	Non-GM
Cocoa powder	1.5	9.4	Non-GM
Soy lecithin	0.15	1.42	GM or Non-GM (non-GM usually a requirement)
Other ingredients (salt, raising agents)	1.15	0.98	Non-GM
Total cost of raw materials		***1,068.7***	

5.4.2 Non GM ingredients: availability/costs

For the ingredients for which GM derived material may be used, Table 21 and Table 22 detail current prices/availability of non-GM alternatives and the implications of using certified non-GM ingredients:

- the main ingredient base is derived from products (dairy, cocoa, wheat and sugar) for which GM technology is currently not available (and / or is not expected to be available commercially in the next three years) and hence there has been no requirement to actively change raw material procurement procedures;

- **For the ingredients that may be derived from GM soy or maize, the vegetable oil blends, maize flour and soy lecithin account for just over 17% of total ingredient use by weight but only 6.6% of ingredient costs. The additional cost of using only certified non-GM ingredients and switching to vegetable oil blends that are not derived from soy oil has probably added about 0.23% to 0.43% to total raw material costs**;

- **Over the next 1-3 years, the additional cost of using only certified non-GM ingredients is likely to increase but remain fairly small insignificant (at about 0.25% to 0.45%).**

Table 21: Chocolate based confectionery biscuit ingredients: GM versus non-GM alternatives

Ingredient	Non-GM availability	Price differential (non-GM being higher priced)
Blended vegetable oils	Good availability from oilseeds that are not derived from GM crops (rapeseed, sunflower and palm). Reasonable availability can also be expected over the next 1-3 years (see above).	Current price differentials between blended oils made from non-GM sourced oils and blend that may include GM derived soy oil (and/or GM derived rapeseed or cottonseed oil) fall within a range of about 3% to 13%. As indicated above, the future price of oils is subject to uncertainty. Future differentials can be expected to at least be the same as current levels.
Maize flour	Currently, there is reasonable availability of certified non-GM maize from which flour is manufactured. Almost all maize flour used in the EU is probably derived from certified non-GM maize origins from within the EU. Over the next 1-3 years availability of certified non-GM maize in Europe is likely to remain reasonably easy to access.	Price of non-GM maize typically trades at the same price or a small premia (up to 3%) to maize not provided with certified non-GM origin status. The low incorporation levels (5% maximum) means that the use of certified non-GM maize has a very small impact on the raw material costs of production (accounting for an additional €0.4 or 0.04% to total ingredient costs). Price of non-GM maize in Europe unlikely to alter significantly in the next 1-3 years.
Soy lecithin	Derived from soy oil or rape oil. Currently, there is reasonable availability of certified non-GM soy oil: see section 3) from which lecithin is manufactured, and most lecithin used in the EU food sector are probably derived from certified non-GM soy or derived from EU origin (non-GM) rape oil. Over the next 1-3 years availability of certified non-GM soy oil is expected to fall, although availability of non-GM rape oil in Europe is likely to remain reasonably easy to access.	The very low incorporation levels for lecithin in this category of product means that the use of certified non-GM lecithin raw materials has a very small impact on the raw material costs of production (the non-GM requirement adds about 0.05% to total raw material costs). Any future widening of the GM versus non-GM soy oil price differential (as expected in the next 1-3 years) will increase the cost of this raw material but its very small proportion of total ingredient costs means that there will be only a minute additional cost (adding another €0.2 euros to the raw material cost of one tonne of finished product).

Current price differentials (Spring 2005): sunflower oil €557/tonne, rapeseed oil €517/tonne, GM derived soy oil €426/tonne (all CIF Rotterdam prices). The certified non-GM soy oil price is about €480/tonne.

Table 22: Impact of using non-GM derived ingredients: chocolate-based confectionery biscuit (€/tonne of finished product)

Ingredient	Baseline cost (can use GM ingredients)	Additional cost of using non-GM ingredient: current	Additional cost in 1-3 years time
Blended vegetable oil	55.56	+1.48 to +3.6	+1.48 to +3.6
Maize flour	13.95	+0.39	+0.39
Soy lecithin	0.84	+0.58	+0.785
Total of these ingredients	70.35	+2.45 to +4.57	+2.655 to +4.775
Other raw materials (chocolate, wheatflour, sugar, cocoa, salt, raising agents)	995.95	0	0
Total raw material costs	1,066.30	+2.45 to +4.57	+2.655 to +4.775
% change in cost of raw materials		***+0.23 to +0.43***	***+0.25 to +0.45***

Notes:

1. Blended oils based on a mix of oils from rapeseed, soybeans, sunflower and palm
2. Current price differentials between the different oils are assumed to continue in 1-3 years. Based on forecasts of future projected prices this is probably a conservative assumption
3. Non-GM maize used as base material for maize flour assumed to trade at a 3% price premium relative to any origin maize both currently and in 1-3 years time

5.5 A pizza[31]

5.5.1 Raw material use

The main ingredients used in a typical pizza product are mostly from crops/products for which there are no current GM 'equivalents' (Table 23). Of the ingredients that may be derived from GM origins, blended vegetable oil (excluding soy oil) is the main ingredient of relevance, accounting for about 2.2% of product weight and 1.1% of raw material costs. The blended oils used may be a mix of a number of oils such as rapeseed, sunflower and palm oil and commonly, the products used are required to be certified as from non-GM origins. Of the other minor ingredients, the dextrose and the soy lecithin may be derived from GM origins, (the modified maize starch could be, but is probably from a non-GM type such as "waxy" maize),and some of the additives (mono and diglycerides, ascorbic acid, sodium ascorbate and enzymes) are mostly derived from production process using GMMs and which could also (depending on their geographical origin) be utilising a GM-based substrate such as maize).

[31] Example a deep pan base, ham and mushroom topping

Table 23: Example deep pan mushroom and ham pizza ingredient composition (per tonne equivalent)

Ingredient	Approximate incorporation %	Cost of ingredient (€)	Current status: GM versus non-GM
Wheat flour	50	187	Non-GM
Cheese	13.5	371	Non-GM
Ham	7.9	162	Non-GM
Mushrooms	8.1	159	Non-GM
Tomato puree	5.9	7.1	Non-GM
Vegetable oil	2.2	10.46	Non-GM (a blend of oils such as rapeseed, sunflower and palm oils, excluding soy oil, unless certified non-GM)
Modified maize starch *	0.1	0.98	GM or non-GM (non-GM usually a requirement)
Dextrose	1.5	9.11	GM or non-GM (GMM enzymes may also be used as a processing aid)
Lecithin	0.3	2.84	GM or non-GM (non-GM usually a requirement)
Antioxidant and flour treatment: ascorbic acid & sodium ascorbate	0.34	2.74	GM (including GMMs) or non-GM
Other ingredients (salt, tapioca starch, whey powder, enzymes)	3.4	8.57	Non-GM
Total cost of raw materials		***920.8***	

* Note: modified maize starch is frequently derived from "waxy" maize for which currently there are no GM cultivars

5.5.2 Non GM ingredients: availability/costs

For the ingredients for which GM-derived material may be used, the main current prices/availability of GM versus non-GM alternatives are as follows (Table 24 and Table 25):

- the main ingredient base is derived from products (wheat, dairy, meat, mushrooms and tomato paste) for which GM technology is currently not available (and/or is not expected to be available commercially in the next three years) and hence there has been no requirement to actively change raw material procurement procedures;

- **For the ingredients that may be derived from GM soy or maize, the vegetable oil blends, modified maize starch (see note above concerning "waxy" maize), soy lecithin, dextrose and additives / processing aids account for 4.44% of total ingredient use by weight and only 2.6% of ingredient costs. The additional cost of using only certified non-GM ingredients and switching to vegetable oil blends that are not derived from soy oil has probably added about 0.2% to 0.24% to total raw material costs**;

- **Over the next 1-3 years, the additional cost of using only certified non-GM ingredients is likely to increase but remain fairly small insignificant (at 0.25% to 0.29%). However, any requirement to use non-GMM-derived ingredients may be undeliverable in the short to medium term.**

Table 24: Pizza ingredients: GM versus non-GM alternatives

Ingredient	Non-GM availability	Price differential (non-GM being higher priced)
Blended vegetable oils	Good availability from oilseeds that are not derived from GM crops (rapeseed, sunflower and palm). Reasonable availability can also be expected over the next 1-3 years (see above).	Current price differentials between blended oils made from non-GM sourced oils and blend that may include GM derived soy oil (and/or GM derived rapeseed or cottonseed oil) fall within a range of about 3% to 13%. As indicated above, the future price of oils is subject to uncertainty. Future differentials can be expected to be at least the same as current levels.
Modified maize starch	Derived from maize, probably from a "waxy" (non-GM) type. Currently, there is reasonable availability of certified non-GM maize from which modified starches are manufactured. Almost all modified maize starch used in the EU is probably derived from certified non-GM maize originating within the EU. Over the next 1-3 years availability of certified non-GM maize in Europe is likely to remain reasonably easy to access.	Price of non-GM maize typically trades at the same price or a small premium (up to 3%) to maize not provided with certified non-GM origin status. The very low incorporation levels (~0.1%) means that the use of certified non-GM maize has a very small impact on the raw material costs of production (accounting for an additional €0.02 or 0.002% of total ingredient costs). Price of non-GM maize in Europe unlikely to alter significantly in the next 1-3 years.
Soy lecithin	Derived from soy oil (small quantities of lecithin from rape oil are available). Currently, there is reasonable availability of certified non-GM soy oil: see section 3) from which lecithin is manufactured, and most lecithins used in the EU food sector are probably derived from certified non-GM soy or derived from EU origin (non-GM) rape oil. Over the next 1-3 years availability of certified non-GM soy oil is expected to fall, although availability of non-GM rape oil in Europe is likely to remain reasonably easy to access.	The very low incorporation levels for lecithin in this category of product means that the use of certified non-GM lecithin raw materials has a very small impact on the raw material costs of production (the non-GM requirement adds about 0.1% to total raw material costs). Any future widening of the GM versus non-GM soy oil price differential (as expected in the next 1-3 years) will increase the cost of this raw material but its very small level of inclusion means that there will be only a minute additional cost (adding another €0.41 euros to the raw material cost of one tonne of finished product).
Dextrose	Usually derived from maize starch (enzymes used in the manufacturing process, such as amylase, glucose isomerase and pullulanase may be GMM derived). Currently, there is reasonable availability of certified non-GM	Non-GM maize typically trades at the same price or a small premium (up to 3%). Very low incorporation level (1.5% maximum) means use of certified non-GM maize has a very small impact on the raw material costs of production (accounting for an additional €0.29 or 0.023% of total ingredient costs).

	maize from which starches are derived. Almost all maize starch used in the EU is likely to be derived from certified non-GM maize originating within the EU. The manufacturing process usually uses GMMs. Dextrose may also be derived from wheat and potato, currently non-GM	Price of non-GM maize in Europe unlikely to alter significantly in the next 1-3 years. Any possible future requirement to avoid using GMMs in the manufacture of enzymes used in dextrose manufacture would probably result in short to medium term problems of supply availability
Emulsifier (mono- & diglycerides), Antioxidant (ascorbic acid, sodium ascorbate, enzymes)	Derived from soya oil during the refining process. Fermentation products that uses glucose as their main energy substrate. The most common raw material is maize. Abundant availability of certified non-GM maize in the EU both currently and expected in the next 1-3 years. If imported from countries outside the EU, likelihood of GM maize having been the origin is much higher (this likelihood can be expected to increase in the next 1-3 years). The manufacturing process for ascorbic acid usually uses GMMs	The very low incorporation rates for these ingredients means that the impact of using a certified non-GM origin substrate (even if price premia for the base oil were to rise substantially) has a negligible impact on the total cost of raw materials. Any move to require labelling of GMMs and an active policy taken up by food manufacturers to avoid such labelling would require a move away from current manufacturing methods. For the time period of 1-3 years, any such move is likely to result in a lack of available supplies of non-GMM derived products. In the longer term, supplies might become available if manufacturers perceive this to be a consistent and longer-term based demand and make the necessary investment in non-GMM based production facilities. It is not possible to estimate the price implications for this hypothetical scenario, although at the end product level, even a substantial increase in the price of these ingredients, based on not using GMMs (e.g. a doubling in price) would have a very small impact on the total cost of raw materials

Current price differentials (Spring 2005): sunflower oil €557/tonne, rapeseed oil €517/tonne, GM derived soy oil €426/tonne (all CIF Rotterdam prices). The certified non-GM soy oil price is about €480/tonne.

Table 25: Impact of using non-GM derived ingredients: pizza ingredients: €/tonne of finished product)

Ingredient	Baseline cost (can use GM ingredients)	Additional cost of using non-GM ingredient: current	Additional cost in 1-3 years time
Blended vegetable oil	10.19	+0.27 to +0.66	+0.27 to +0.66
Modified maize starch	0.96	+0.02	+0.02
Soy lecithin	1.67	+1.17	+1.58
Dextrose	8.82	+0.29	+0.29
Mono- & diglycerides, ascorbic acid and sodium ascorbate	2.74	+0.1	+0.1 (but supply problems if GMMs to be avoided
Total of these ingredients	24.38	+1.85 to +2.24	+2.26 to +2.65
Other raw materials	894.62	Not applicable	Not applicable
Total raw material costs	919	+1.85 to +2.24	+2.26 to +2.65
% change in cost of raw materials		***+0.2 to +0.24***	***+0.25 to +0.29***

Notes:

1. Blended oils based on a mix of oils from rapeseed, soybeans, sunflower and palm.
2. Current price differentials between the different oils are assumed to continue in 1-3 years. Based on forecasts of future projected prices, this is probably a conservative assumption.
3. Non-GM maize used as base material for maize flour assumed to trade at a 3% price premium relative to any origin maize both currently and in 1-3 years time.

5.6 A ready meal[32]

5.6.1 Raw material use

The main ingredients used in this example ready meal are mainly derived from meats / processed meats (Table 26). The primary ingredient, chicken breast, (which accounts for 72% of ingredient costs) is probably derived from animals fed on a diet from which GM-derived protein has been excluded. Of the other (minor) ingredients, the modified maize starch, dextrose and vegetable oil may be derived from GM origins, and the additive sodium ascorbate is probably obtained from a production process using a GMM and based on a substrate derived from a GM crop such as maize.

[32] Chicken-based

Table 26: Example ready meal ingredient composition (per tonne equivalent)

Ingredient	Approximate incorporation %	Ingredient cost (€)	Current status: GM versus non-GM
Chicken breast (based on using non GM protein in the diet)	42	1,575	GM or non-GM (non-GM in terms of protein part of diet)
Pork	12	246	Non-GM
Bacon	11	302.5	Non-GM
Pork fat	5.5	41.25	Non-GM
Wheat flour	1.5	5.61	Non-GM
Modified maize starch *	1	9.75	GM or non-GM (usually a requirement)
Dextrose	0.1	0.61	GM or non-GM (GMM enzymes may also be used as a processing aid)
Vegetable oil	0.5	2.38	Non-GM (a blend of oils such as rapeseed, sunflower and palm oils, excluding soy oil, unless certified non-GM)
Sodium ascorbate; Sodium citrate	0.1	0.71	GM (including GMMs) or non-GM
Other ingredients: salt, etc	1.3	1.28	Non-GM
Total cost of raw materials		***2,185.09***	

* Note: modified maize starch is frequently derived from "waxy" maize which has not undergone GM. Ingredient list excludes ingredients of water-based components such as gravy.

5.6.2 Non GM ingredients: availability/costs

For the ingredients for which GM derived material may be used, the main current prices/availability of GM versus non-GM alternatives are as follows (Table 27 and Table 28):

- the main ingredient base is derived from products (wheat, dairy, meat, mushrooms and tomato paste) for which GM technology is currently not commercially available (and / or is not expected to be in the next three years) and hence there has been no requirement to actively change raw material procurement procedures;

- **for the ingredients that may be derived from GM soy or maize, the vegetable oil blends, modified maize starch, soy lecithin, dextrose and additives/processing aids account for 4.44% of total ingredient use by weight and only 1.3% of ingredient costs. The additional cost of using only certified non-GM ingredients and switching to vegetable oil blends that are not derived from soy oil has probably added about 0.15% to 0.19% to total raw material costs**;

- **over the next 1-3 years, the additional cost of using only certified non-GM ingredients is likely to increase but remain relatively insignificant (at 0.22% to 0.26%). However, any requirement to use non-GMM derived ingredients may be undeliverable in the short to medium term.**

Table 27: Ready meal ingredients: GM versus non-GM alternatives

Ingredient	Non-GM availability	Price differential (non-GM being higher priced)
Chicken breast	The fresh poultry sector has been the main livestock production sector with a non-GM (protein) requirement in feed (see section 5.1). A significant part of the fresh poultry meat produced in the EU is therefore currently derived from birds fed on a diet that excludes GM soymeal. Reasonable current availability of non-GM soymeal, but expect reduced availability from 2006	For costs of non-GM soymeal see section 5.1. Impact of this additional feed cost largely absorbed by the poultry producing sector – the impact at this part of food ingredient chain has potentially added about 0.9% to total ingredient costs. Over the next 1-3 years, the widening price differential between GM and non-GM soymeal is likely to result in higher costs of production, which will add a further €18 to the cost (adding a further 0.9% to the total ingredient costs)
Blended vegetable oils	Good availability from oilseeds that are not derived from GM crops (rapeseed, sunflower and palm). Reasonable availability can also be expected over the next 1-3 years (see above)	Current price differentials between blended oils made from non GM sourced oils and blend that may include GM derived soy oil (and/or GM derived rapeseed or cottonseed oil) fall within a range of about 3% to 13%. Future differentials can be expected to at least be the same as current levels
Modified maize starch*	Derived from maize. Reasonable current availability of certified non-GM maize from which modified starch is manufactured. Almost all modified maize starch used in the EU is likely to be derived from certified non-GM maize originating within the EU. Over the next 1-3 years availability of certified non-GM maize in Europe is likely to remain reasonably easy to access	Price of non-GM maize typically trades at the same price or a small premium (up to 3%) to maize not provided with certified non-GM origin status. The very low incorporation levels (~1%) mean that the use of certified non-GM maize has a very small impact on the raw material costs (accounting for an additional €0.13 or 0.006% of total ingredient costs). Price of non-GM maize in Europe unlikely to alter significantly in the next 1-3 years
Dextrose	Usually derived from maize starch; enzymes used during manufacturing process, such as amylase, glucose isomerase and pullulanase, may be GMM derived. Availability of maize: see modified maize starch above The manufacturing process uses GMMs	Low incorporation level (1.3% maximum) means use of certified non-GM maize has a very small impact on the raw material costs of production (accounting for an additional €0.02 or 0.001% to total ingredient costs). Price of non-GM maize in Europe unlikely to alter significantly in the next 1-3 years Any possible future requirement to avoid using GMMs in the manufacture of enzymes used on dextrose manufacture would probably result in short/medium term problems of supply availability
Sodium ascorbate	Fermentation product that uses GMM and glucose as the main energy substrate. The most common raw material is maize. Abundant availability of certified non-GM maize in the EU	Very low incorporation rate means the impact of using a certified non-GM origin substrate (even if price premium for the base material were to rise substantially) has a negligible impact on the total cost of raw materials. Any move to avoid GMMs will require a move away from current manufacturing

	both currently and expected in the next 1-3 years. If imported from countries outside the EU, likelihood of GM maize having been the origin is much higher (this likelihood can be expected to increase in the next 1-3 years	methods. For the time period of 1-3 years any such move is likely to result in a lack of available supplies of non-GMM derived products. In the longer term, supplies might become available if manufacturers perceive this to be a consistent and longer term based demand and make the necessary investment in non-GMM based production facilities. It is not possible to estimate the price implications for this hypothetical scenario, although at the end product level, even a substantial increase in the price of these ingredients based on not using GMMs (e.g. a doubling in price) would have a very small impact on the total cost of raw materials

Current price differentials (Spring 2005): sunflower oil €557/tonne, rapeseed oil €517/tonne, GM derived soy oil €426/tonne (all CIF Rotterdam prices). The certified non GM soy oil price is about €480/tonne.

* Note: modified maize starch is frequently derived from "waxy" maize which has not undergone GM.

Table 28: Impact of using non-GM derived ingredients: ready meal ingredients: €/tonne of finished product)

Ingredient	Baseline cost (can use GM ingredients)	Additional cost of using non-GM ingredient: current	Additional cost in 1-3 years time
Chicken breast	1,557	+18	+37
Blended vegetable oil	2.32	+0.06 to +0.15	+0.06 to +0.15
Modified maize starch	9.62	+0.13	+0.13
Dextrose	0.59	+0.02	+0.02
Sodium ascorbate	0.71	Negligible but supply problems if GMMs need to be avoided	Negligible but supply problems if GMMs need to be avoided
Total of these ingredients	1,570.24	+18.21 to +18.3	+37.21 to +37.3
Other raw materials (pork, bacon, pork fat, wheatflour, others)	596.76	Not applicable	Not applicable
Total raw material costs	2,167	+18.21 to +18.3	+37.21 to +37.3
% change in cost of raw materials		**+0.84**	**+1.72**

Notes:

1. Blended oils based on a mix of oils from rapeseed, soybeans, sunflower and palm
2. Current price differentials between the different oils are assumed to continue in 1-3 years. Based on forecasts of future projected prices this is probably a conservative assumption
3. Non-GM maize used as base material for maize flour assumed to trade at a 3% price premium relative to any origin maize both currently and in 1-3 years time
4. Price differentials for soy-based feed used in poultry meat (see section 5.1)

5.7 Non-GM policies: overhead costs

In addition to the higher raw material costs that may arise from operating a non-GM ingredient policy (see sections 5.1 to 5.6 above), there are other overhead-type costs that will arise, dependent upon the size of the business and the complexity of its product and even customer portfolios. Depending on the type of business, these may include:

- *Diversion of staff time*, (e.g. in purchasing, development and quality management, in particular) or a need to employ additional, dedicated staff to establish and maintain systems to deliver traceability and IP/segregation of GM versus non-GM ingredients and to undertake testing;

- *Systems equipment and software to operate a traceability and IP system*;

- *Possible, periodic fees and associated internal management costs in using independent companies to undertake audits* and verification of traceability and IP systems;
- *Adverse costs generated by reduced production capacity and/or utilisation* from having to shut down continuous manufacturing lines for cleaning (e.g. between runs that manufacture lines containing non-GM ingredients and lines that may contain GM-derived ingredients);
- *Having to operate separate storage facilities*. It may also be necessary to invest in additional, separate storage facilities (e.g. separate tanks for GM and non-GM derived vegetable oils);
- *Possible reduced functionality of ingredients* in products resulting in increased levels of wastage/spoilage or reduced product shelf life, and hence more frequent, but shorter, production runs;
- *Changes to the taste and texture of final products* (e.g. possibly arising when a non-GM policy leads to a switching of ingredients).

The extent to which these costs arise varies widely between businesses. For example, a company operating separate manufacturing lines, or at separate times, for products containing both GM derived and non-GM derived ingredients may have higher costs than a company that operates a fully, non-GM ingredient policy. In some cases, therefore, it is known that companies have chosen to use particular non-GM ingredients across their product range – and thus incur additional raw material costs – rather that operate segregated storage and production regimes. In others, it has been a cheaper, overall option to continue with a more expensive raw material such as non-GM soy lecithin, since the potential use of a non-GM alternative (e.g. ammonium phosphatide) only becomes feasible / acceptable if either replacement processing equipment is installed or resultant changes to the end product organoleptic properties are considered insignificant.

Economies of size may also be derived by some (larger) businesses that are not available for smaller operators. Thus, the overhead costs directly attributable to a non-GM policy will vary widely between businesses and are very difficult to quantify (especially as some of the traceability systems costs may now be considered as partially attributable to other trading requirements such as the EU General Food Law Regulation 178/2002).

Nevertheless, whilst the analysis presented in sections 5.1 to 5.6 has indicated that, for some products in the food sector, the costs of switching raw materials away from GM origins to certified non-GM sources have been very small, **the associated overhead cost of making, and maintaining, this policy is likely to have been significantly higher.**

One source in the feed sector estimated that these overhead costs amounted to the equivalent of adding about 10%-12% to the cost of producing compound feed; an additional cost that has not been passed on down the supply chain but absorbed by the feed sector. FEDIMA (The European Federation of Intermediate Products Industries for the Bakery and Confectionery sector) suggested that the additional costs to their industry were equal to about 2%-3% of annual turnover (€100 - 150 million).

Appendix 1: Ingredients potentially derived from GM origins

This Appendix describes those materials that are legally defined as *"ingredients"* and which will generally be required to be identified on food and feed labels. Thus, they will always be declared and, if they have been derived from GMOs, will need to declare that fact.

In the case of foods, there are a few limited exemptions from declaration of ingredients, the principal ones of relevance to the GM debate being:

- substances (including ingredients) used as carriers for an additive, providing they are used in amounts that are no more than necessary for the purpose;

- beverages with an alcoholic strength greater than 1.2% by volume.

As indicated in the body this report, the "ingredients" of principal concern are those derived from soy and maize. Food materials derivatives from rapeseed are essentially limited to the oil (discussed in section 3); those from cotton which are the modified celluloses (described in Appendix 2).

A1.1 Soy

Soy is grown principally for its oil content, with the protein meal residues from the extraction process being widely used as animal feed. Whole beans, are sold in limited quantities. Its principal food uses are through the following ingredients, extracted directly or indirectly from soybeans or obtained by further processing of soy derivatives in the presence of other food materials. Derivatives legally defined as "additives" are considered in Appendix 2.

A1.1.1 Enzyme active full fat (whole) soy flour

"Full fat", enzyme-active soy flour; about 42% protein, has been subject to only minimal processing and retains all the natural oil, protein functionality and enzyme activity. It is, essentially, milled whole beans from which the hulls may / may not have been removed.

Enzyme active soy flour acts as a dough conditioner for any baked products and thereby improves the workability and lengthens the working time of the dough. It therefore plays an important function in highly automated baking systems. It is also used as a bread improver in some processes, where the lipoxygenase enzymes bleach the carotenoid pigments in wheat flour during the baking process, resulting in whiter bread.

It is typically used at a level of between 0.4 – 0.7% of wheat flour in the recipe, the precise level being dependent upon the flour quality and type (season and variety dependent).

Full fat soy flour also functions as an emulsifier and can be used as a partial egg replacement in some bakery applications.

A1.1.2 Defatted soy flour / grits
Defatted soy flour is finely-ground, defatted soy meal and contains about 52% protein. It is used as an ingredient and supplement to cereal products (wheat, corn, rice), where it provides an inexpensive source of protein. It can be used in a wide variety of products including bread, meat products, weaning foods, breakfast cereals, cakes, pastas, and tortillas.

Defatted soy flour / grits may also be texturised, generally by extrusion. Textured soy protein is sold in a range of sizes, ranging from chunks to fine mince, and may be flavoured to simulate different meats. It is used either in "meat-free" meals such as vegetarian chilli ("con carne") or as a meat extender (subject to labelling and legal constraints) in traditional meat products such as burgers, sausages and pies.

A1.1.3 Soy protein concentrate
Soy protein concentrate (SPC) is made wholly from defatted soy meal by removing the soluble carbohydrates by further processing. This process also removes some of the less pleasant flavours.

SPC consists of about 70% protein and is used in either powder form in baked goods, dairy applications and comminuted meat products, or can be texturised and used as a meat analogue, where its bland flavour relative to the basic TSP (above) makes it a better substrate for added meat-like flavours.

Soy protein concentrate is highly digestible and is therefore also used where concentrated doses of protein are required in specialist foods for people with digestibility problems or where protein nutrition is important, such as children, pregnant / lactating women, the elderly and sick.

A1.1.4 Soya protein isolate
Whereas it is the carbohydrates that are solubilised during the manufacture of SPC, it is the protein fraction of defatted soy meal that is solubilised and separated during the manufacture of soya protein isolate. The protein solution is then precipitated, either as a powder or "spun" into fibres that can be further compacted into small pieces. It comprises 90% - 92% protein.

Soy protein isolate (SPI) is used as an ingredient in high-protein foods including dairy foods, nutritional supplements, fine-textured meat products such as frankfurters, infant formulas, nutritional beverages, cream soups, sauces, and snacks.

It is also the source of protein in soy-based milk replacers. Due to its high protein content, soy protein isolate is often used in specialist foods where protein quality is important, such as for young children, pregnant / lactating women, the elderly and sick.

A1.1.5 Hydrolysed soy proteins
This section is also relevant to maize protein (see below).

Both crude and refined soy protein products (alone or in mixtures with other plant proteins such as maize) may be broken down by acid or enzymatic hydrolysis to produce a wide range of flavouring materials ("hydrolysed vegetable proteins" - HVPs), flavour enhancers and other functional derivatives, including "hypo-allergenic" infant foods. By varying the type of protein used, the hydrolysis conditions, and the inclusion of other reagents, it is possible to adjust the flavour of the hydrolysates to imitate a wide range of savoury notes. These hydrolysates may be used alone or in combination with other flavour materials such as herbs, spices, MSG, salt, etc as the "seasonings" for a wide range of foods such as meat products, savoury sauces and snackfoods etc.

Partial hydrolysis of soya protein isolate significantly increases its ability to form stable "whipped foams", whilst more complete hydrolysis results in enhanced emulsifying capacity. Hydrolysed proteins may also be used to contribute to the 'mouth feel' of soft drinks, (i.e. to give a rich, smooth texture). Correctly applied proteolysis of inexpensive materials such as soya protein can increase the range and value of their usage, as indeed occurs naturally in the production of soy sauce.

A1.1.6 Soy sauce

Traditional soy sauce is produced by a lengthy fermentation process, to which other materials such as wheat or rice may also be added. The traditional production takes at least one year and normally uses selected, speciality beans that are unlikely to have a GM origin. However, many cheaper "soy sauces" are available, based on blends of HVPs with other ingredients, which may be derived from a variety of plant origins or mixtures of plant proteins. As above, the production process may be chemical or enzymatic (protease).

A1.1.7 Other soya protein products

Traditional ***soy "milk"*** consists mainly of an aqueous extract of soybeans, from which hulls and other solids have been removed. The European market for traditional soy-based products has grown considerably in recent years and now includes a wide range of dairy analogues based on soy.

- ***Tofu*** is a form of soy cheese, produced in an analogous manner by coagulating soya "milk" with calcium salts, pressing and separating from the soy "whey"
- ***Tempeh*** is produced by the controlled fermentation of cooked soybeans with a Rhizopus mould (tempeh starter), which binds the soybeans into a compact white cake, with a flavour of mushrooms. It used as ingredient in soups, spreads, salads and sandwiches
- ***Miso*** is a rich, salty paste made from soybeans and grain (e.g. rice), fermented with salt and matured for up to 3 years. It is a powerful flavouring used to flavour a variety of foods such as soups and sauces, dressings, marinades and pâtés

A1.1.8 Soy oils

The general principles relating to the further processing and modification of oil are also applicable to refined maize oil (see below).

The oil is extracted from milled beans by solvent extraction, refining, bleaching, deodorising, etc and may be sold as such, used as an ingredient in a wide range of foods or further processed. During the numerous refining processes, a number of specialist by-products, such as lecithin, free fatty acids, tocopherols and phytosterols (examined briefly below) are also obtained.

The basic, extracted oil is suitable for only limited direct use as a food ingredient in the manufacturing industry. A range of physical, chemical or enzymic modifications may therefore be applied to the oil, either alone or blended with other oils, to change properties such as chemical structure, melting point, crystal size and structure, emulsifying properties and even nutritional profile, in order to produce fats tailored for specific applications such as spreadable fats (margarines / minarines), frying oils, bakery fats ("shortenings") and speciality cocoa butter replacements for chocolate manufacture.

Hydrogenation has been traditionally used but more tailored molecular changes can be introduced by the selection of specific enzymes (lipases, described in section 3.2.6 and Appendix 3, below) either to modify an individual oil or to cross-react with fats / oils of other types or individual fatty acids. The lipases are potentially derived from GM micro-organisms.

Usage levels in final foods range from 100% when sold as such (oils and so-called shortenings), through 80% - 40% (margarines, minarines and low-fat "yellow" spreads) down to "traces" when oils are present as a result of previous use as a carrier for flavouring materials, anti-dust agents etc. Other major uses include mayonnaise / other salad dressings, pastry, bread and flour confectionery and ready meals.

A1.1.9 Lecithin

Lecithin is a complex phosphatide separated from the crude oil at the degumming stage. It possesses powerful emulsifying properties and is also sold in limited quantities through health food outlets. It is legally classified as an "additive" and described in more detail in Appendix 2.

A1.1.10 Tocopherols

A range of tocopherols are also obtained from the refining process and used as anti-oxidants or as vitamin E precursors, either as natural extracts or after chemical modification (e.g. tocopherol succinate). These are described in Appendix 2.

A1.1.11 "Phytosterols" - sterols, stanols and their esters

Phytosterols are derived by further purification, processing and separation of an extract obtained during the deodorisation stage of oil refining. The esters are then produced from the phytosterols using fatty acids or triglycerides, using the esterification processes outlined above.

Sterols, stanols and their esters are of interest for their potential health benefits and are increasingly used in a number of "functional" foods, although their use is subject to formal authorisation on a case-by-case basis and their daily intake restricted to 3 grams.

Approved uses include yellow fats, yoghurts and dairy drinks, cheeses, and salad dressings, with a range of further applications in the pipeline for meat products, cereal products and fruit juices.

A1.1.12 Isoflavones

Isoflavones are derived from the carbohydrate fraction removed during protein concentration. They are known to possess powerful antioxidant properties and a number of claims are made for their potential health benefits, including from cardiovascular / cholesterol protection / arterial plaque growth reduction, bone density and prevention of cancer.

A1.1.13 Fatty acids

Fatty acids are extracted and are widely used as emulsifiers. Examples include mono- and di-glycerides (E471), a range of glyceride esters (E472a-e series). Further details of these ranges of fatty acids and their esters are given in Appendix 2.

A1.1.14 Soy fibre
Two basic types of soy (dietary) fibre are commercially available:

- Soy bran is derived from hulls (the outer covering of the soybean), removed during initial extraction / cleaning stages and further refined for use as an ingredient in foods such as muesli and other products where fibre supplementation is considered desirable
- 'Okara' is the pulp fibre obtained as a by-product of soy "milk" production. It contains low levels of residual protein and is used in baked flour products, breakfast cereals and vegetarian foods.

[Soy isolate fibre, also known as structured protein fibre (SPF), is soy protein isolate in a fibrous form, and not strictly fibre in the dietary sense.]

A1.1.15 ESBO
Epoxidised soybean oil (ESBO) is used as a plasticiser and stabiliser in polyvinyl chloride (PVC) gaskets of metal lids used to seal glass jars and bottles. The gasket forms an airtight seal preventing microbiological and other contaminations. This type of packaging is common for baby foods packed in glass jars and bottles. It can also be present in PVC-based lacquers used to coat metal cans and easy-open can lids.

It has recently been the subject of concerns related to its reaction with breakdown products from the PVC and its migration into the foods concerned. It is possible to replace it for many purposes with a lecithin derivative.

A1.2 Maize

A1.2.1 Starches (natural /acid /heat treated)

Starch slurry production
The production process for maize starch is outlined as follows:

The maize grains are softened by "steeping" under controlled conditions for up to 40 hours prior to being lightly milled to break up the kernel and release the oil-bearing maize germ. After the germs have been separated, a "slurry" mixture of starch, protein and fibre is obtained. This is finely ground, and the fibres removed by filtration. The starch and proteins are separated by centrifugation. In the final stage, the product is washed to minimize proteins and obtain the "starch slurry", which is either dried or used as a feedstock for hydrolysis to produce glucose syrups and dextrose.

The process is summarized in Figure A1:

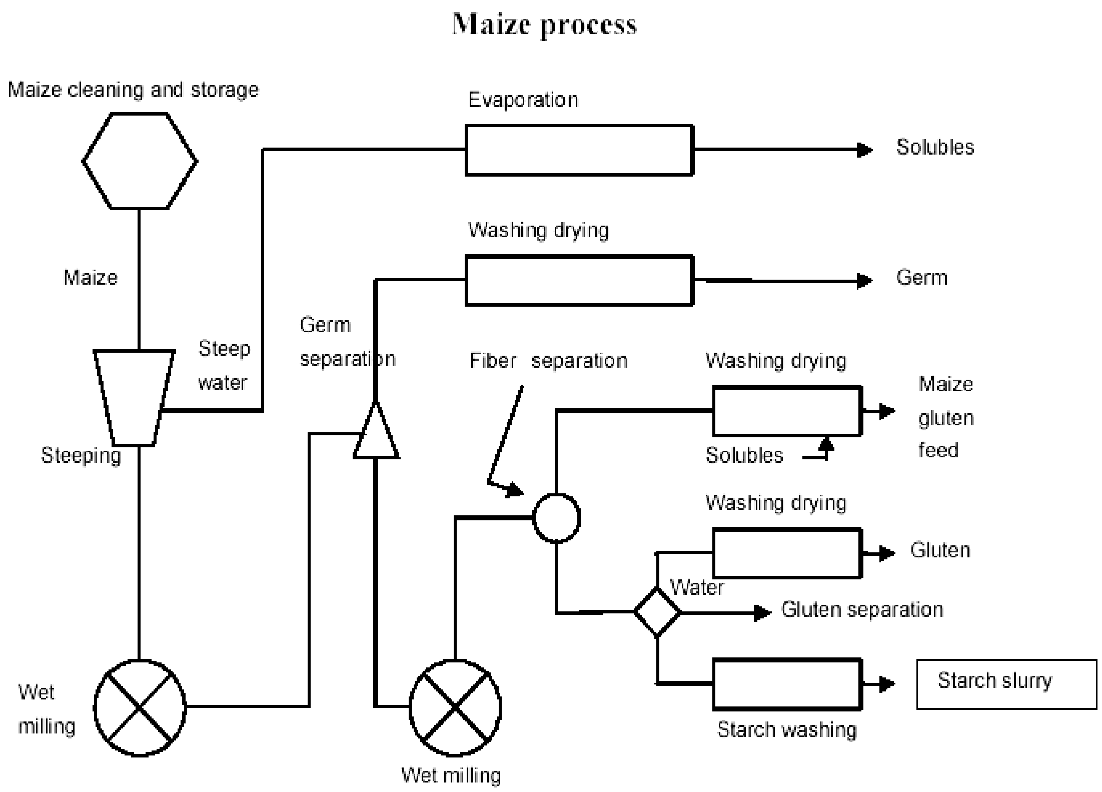


Figure 1: Source: UK Competition Commission 2002

Milling co-products
Maize kernels contain approximately 60% starch, 11% fibres, 8% protein and 4% oil, with the remainder being water and mineral salts.

The starch milling process results in a range of co-products, in addition to starch slurry, including:

- maize gluten: the water-insoluble protein complex
- crude maize oil: crude oil is produced from crushed maize germs and is then further refined and processed
- feed ingredients: the milling process also results in the co-production of other materials such as fibre, meal, germ cake and bran, all used as animal feed. Fibre and bran are also used in human foods:
    - Corn germ meal is a by-product from the extraction of oil. It contains typically 20-21% protein and 90% dry matter
    - Corn gluten feed is a mixture of the hulls & fibre fraction with steep water, corn germ meal and other process residuals
    - Corn gluten meal is the dried gluten from the gluten concentration, containing approximately 60% protein and 90% dry matter
    - Corn steep liquor, a high protein by-product, is often a constituent of corn gluten feed, but may be sold in its own right with for cattle feed or as a pellet binder; it contains approximately 23% protein and 50% dry matter.

Other starch products
The starch slurry can also be treated to produce a range of starch products with different properties:

- ***Unmodified or native starches***, produced directly by drying the slurry
    - These are used in various food applications (for example, dairy products, bakery products, batter coatings, extruded snackfoods, prepared meat products) and also in food-related, non-food applications (for example, paper and corrugated boards)
    - Pre-gelatinised starches are used in soups / gravy mixes and bakery products
    - The product sold in some countries as "cornflour" is, in fact, natural maize (corn) starch.
- ***Modified starches***, produced by the application of physical processes, for example roll-drying, extrusion, spray drying, heat/moisture treatment etc or chemical modification involving the replacement of some hydroxyl groups usually by ester or ether groups
    - Modified starches are used in dairy products, convenience foods, prepared meat products etc and non-food uses such as paper and corrugated board.

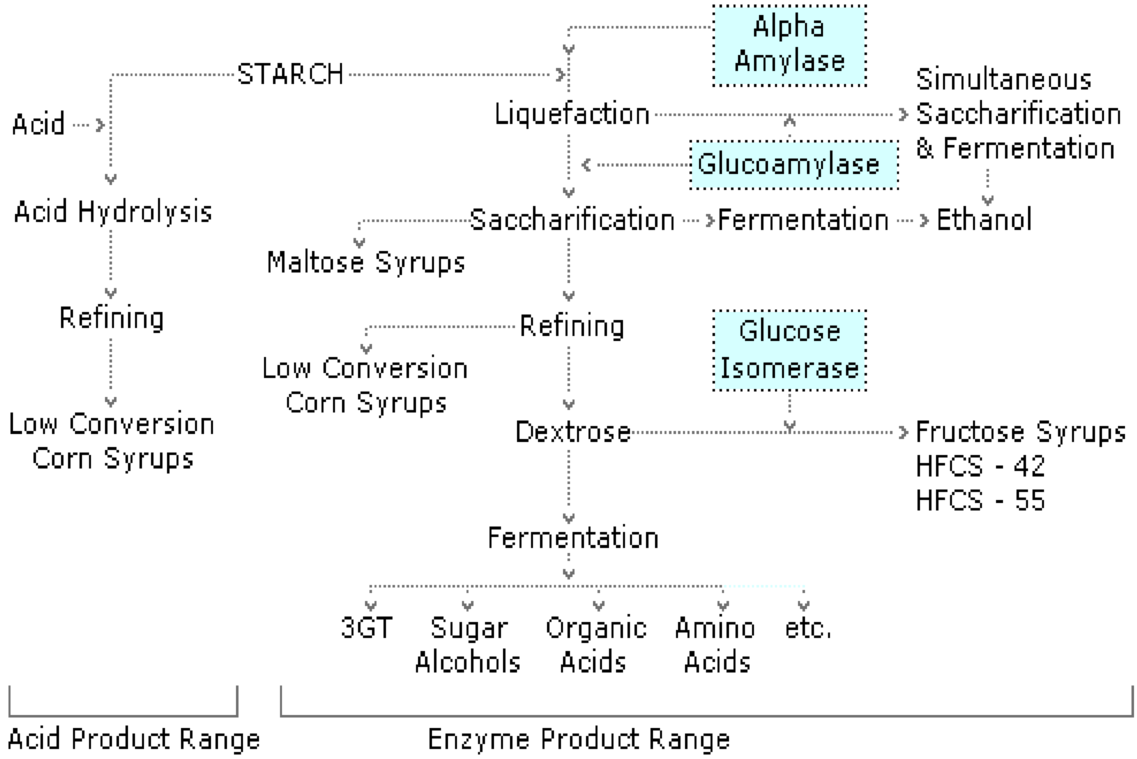
Natural starches, or any starch that has been modified either by physical means (e.g. heat, acid or alkali) or by enzymes, are regarded for labelling law purposes as "unmodified" and may be described in an ingredient list simply by the generic term "starch", without indicating the origin or the type of treatment that has been used (except if it is likely to contain gluten, when the wheat etc origin is required). Since many natural starches can be interchangeable, the consumer is not likely to be aware of their crop origin.

Chemically-modified starches, where the starch has been reacted with any of a range of designated chemicals, are regarded legally as **additives** (see Appendix 2) and must be described as "modified starch" for labelling purposes. Two points should be noted:

- Although they have been allocated E numbers, these do not have to be given on food labels;
- The term "modified" relates to the chemical modification and is totally separate from any requirement related to GM derivation.

A1.2.2 Starch hydrolysis and glucose syrups

Starch may be hydrolysed, using either acid or enzymes to produce a range of glucose syrups, crystalline sugars, starch-based sweeteners and other products. **Figure A2** shows an overview of the range of products and the processing involved.



Source: Genencor International: Grain Milling: http://www.genencor.com/wt/gcor/grain

Glucose is a member of the naturally occurring class of chemical compounds, “sugars”, which also includes fructose, dextrose, maltose and ordinary white sugar (sucrose). ***Glucose syrup*** is a concentrated solution of glucose; ***glucose blends*** are syrups made from glucose to which other ingredients, such as fructose, have been added.

A1.2.2.1 Glucose syrups and blends

Glucose syrups and blends as a category cover a wide variety of products containing glucose and other natural sweeteners, notably fructose, and are distinguished by a number of factors including:

- “Dextrose equivalent”: an expression of the sweetness in terms of dextrose (for the food industry, dextrose and glucose are synonymous terms). The DE of glucose syrups and blends ranges from 20 to 99. Glucose syrup can be combined with other natural sweeteners to produce blends that replicate to a greater or lesser extent the sweetness of sugar (sucrose). Isoglucose with a fructose content of 42% is equivalent in sweetness to sugar.[33]
- Sugar profile: glucose syrups and blends may have a differing content of maltose and dextrose, depending on the type of hydrolysis applied
- Fructose content: glucose syrups are sold in different blends which may contain fructose and/or sucrose in varying proportions
- Additional variables such as pH value, sulphur dioxide (SO2) levels, colour and dry solid content

[33] 42% fructose / 58% glucose is the highest blend which can be produced by the isomerisation process. In order to achieve higher fructose blends, it is necessary to apply an additional conversion process.

Either wheat or maize (principally, although other feedstocks such as rice, tapioca and potatoes) can be used as the raw materials for the production of glucose syrups and many modern plants are capable of using both. There were, historically, conflicting views as to whether maize and wheat actually produce identical glucose syrups and blends and whether it is possible to substitute between them. However, it is now widely recognised that the glucose syrups and blends produced from maize and wheat are equivalent products, which can be substituted for each other in their applications.

Uses of glucose syrups and blends

All sugars are to a greater or lesser extent sweet, and glucose syrups and blends are widely used as an alternative to sugar or sucrose in applications such as confectionery, soft drinks, preserves, jellies and fruit preparations, dairy, bakery, syrup mixes, snacks and ice cream.

Glucose syrup is also used as a fermentation feedstock for alcoholic beverages such as beer and cider, certain vitamins and additives such as citric acid, lysine, antibiotics, insulin and yeast production.

Glucose syrups and blends also have functional properties that provide specific processing and product benefits. In sugar confectionery, for example, glucose syrups are used not only for their sweetening properties but also for functional properties such as viscosity, colour, neutral taste, odour and bulk.

Glucose syrups and blends also serve as starting materials for a series of chemical conversions (see below).

A1.2.2.2 Other starch-based sweeteners

In addition to glucose syrups and blends, a number of other sweeteners are also derived from maize starch:

- *Maltodextrins and spray-dried glucose:* normally produced by the action of alpha-amylase on gelatinised (heat-treated) starch:
- *Crystalline dextrose* is obtained from the complete hydrolysis of starch, followed by purification and crystallization.
    - It has a DE of greater than 99. It is used in bakery and other food applications.
- *Polyols: g*lucose syrups and blends can be hydrogenated catalytically into polyols, i.e. sugar alcohols. These are used in a range of applications including chewing gum, confectionery and pet-food applications.

A1.2.3 Dextrins / maltodextrins

Dextrin is the generic term for a group of starch-derived materials with a molecular size between starch and low molecular weight sugars (oligosaccharides). They are produced by enzymatic conversion of the starch, with the assistance of food acids. The starches commonly used are maize, potato and wheat. Both the maize starch (depending on geographic origin) and the enzymes used (amylase, glucose isomerase and pullulanase) have the potential to be derived from GM origins.

Their principal application in foods is as a thickener or, in some cases as bulking agents or carriers:

- soups and sauces

- dessert mixes
- calorie-reduced products (as fat replacers)
- carriers for vitamins, flavours and colours etc

Maltodextrins have a DE of between 1 and 20; spray-dried glucose generally between DE of 20 and 95. They contain a range of non-sweet sugars.

They are sold in powder form for use in food applications where only moderate sweetness is required (for example, in baby foods, coffee whiteners, creamers, instant foods, sports drinks etc).

Resistant maltodextrin is used to add soluble dietary fibre to clear beverages without a noticeable effect on flavour, texture or appearance and can help mask off-flavours such as the bitter taste in soy-protein enriched drinks. It is also a component of "sports drinks" as an aid to managing blood glucose before, during and after exercise.

Cyclodextrins are used to encapsulate herb, spice and flavour oils (and also vitamins) to preserve the quality of their flavour and to aid their dispersion into aqueous systems.

A1.2.4 Polyols / sugar alcohols

Polyols are used as alternatives to sugars in a wide range of sugar-free and reduced sugar products, including frozen desserts, baked goods and fruit spreads, confectionery and chewing gum. In addition, they function well in fillings and frostings, canned fruits, beverages, yogurt and tabletop sweeteners:

- ***sorbitol***, which has a variety of food and non-food applications;
- ***mannitol***, an isomer of sorbitol, which is a suitable sweetener for food for diabetics;
- ***maltitol***, used as a low-calorie sweetener, as well as in food for diabetics and in sugar-free confectionery;
- ***xylitol,*** a sweet white crystalline alcohol used especially as a sugar substitute in chewing gum and oral health products.

Polyols do not absorb water in the same way as sugar and, consequently, products containing them do not become sticky on the surface as quickly as the equivalent made with sugar. Since moulds and bacteria do not grow as well on these sweeteners, the polyols also effectively extend product shelf life.

A1.2.5 Fructose / fructose syrup / fructose-glucose syrups

Glucose can be further isomerised by enzymic conversion into fructose / fructose syrups, which may be recombined with glucose to produce and a range of glucose-fructose syrups. Depending on the geographical origins, either or both the raw material and the enzymes used in the hydrolysis (amylase and glucose isomerase) may be derived from GM sources.

Isoglucose is a starch-based fructose, produced by the action of glucose isomerase enzyme on dextrose (in the form of high DE glucose syrups). The isomerisation process can produce glucose/fructose blends containing up to 42 per cent fructose. Application of a further process can raise the fructose content to 55 per cent. Where the fructose content is 42 per cent, isoglucose is equivalent in sweetness to sugar.

Fructose can also be produced in a dry crystalline form of 100 per cent purity from sugar and/or from fructose syrups.

Fructose / fructose syrups are used as a sweetener in a range of food and non-food applications, including soft drinks, ice creams and desserts, jams/fruit preserves, sugar confectionery, baked goods, specially-formulated products for diabetics and in fermentation.

Fructose syrups are generally sweeter than glucose syrups. Fructose blends of varying strengths can serve as a very close substitute for sugar, with the term isoglucose generally used to refer to a 42% fructose blend.

A1.2.6 Maize oil ("corn oil")

Maize oil is used as an ingredient in a wide range of foods or further processed. During refining and subsequent processing, a number of specialist by-products, such as free fatty acids, tocopherols and phytosterols are also obtained.

For further details of generic oil processing and the use of refined derivatives, see soy oil section above.

A1.2.7 Tocopherols

Maize oil is an excellent source of tocopherols, described more fully in Appendix 2.

A1.2.8 Glycerol

Glycerol (glycerine) is the chemical base for all fats and oils and is derived by hydrolysis of vegetable oils (or animal fats).

It is used as a solvent for flavourings and colours, a moistening agent (for example, in baked goods), and an ingredient in flavoured syrups, where its viscosity lends body to the product. With icings and confectionery creams, glycerol prevents crystallization of sugar, improves the texture and allows the use of less sugar, for example in ice cream.

A1.2.9 Maize protein

The protein fraction from starch extraction is primarily used as animal feed but smaller quantities are used as substrates for the production of hydrolysed protein based flavours.

A1.3 Dried egg powder

Commercial dried egg powder has normally been treated with lipase and / or glucose oxidase enzymes (potentially derived from GM micro-organisms) during the production process to improve stability and colour by reducing residual fat and glucose levels. Dried egg powder is widely used in

- cakes and flour confectionery
- pasta products
- desserts

Appendix 2: Additives potentially derived from GM origins

This Appendix describes those materials that are legally defined as *"additives"*[34] and which will generally be required to be identified on food and feed labels.

The law concerning the definitions of additives and "processing aids" and the labelling requirements associated with these is complex but is of direct relevance to the interpretation of some "GM avoidance" policies.

EU legislation defines a 'food additive' as:

> *"any substance not normally consumed as a food in itself and not normally used as a characteristic ingredient of food whether or not it has nutritive value, the intentional addition of which to food for a technological purpose in the manufacture, processing, preparation, treatment, packaging, transport or storage of such food results, or may be reasonably expected to result, in it or its by-products becoming directly or indirectly a component of such foods".*

Certain categories of materials are excluded from this definition:

- processing aids[35]
- flavourings, as defined (Directive 88/388)
- nutrients such as vitamins, minerals and trace elements
- plant protection products.

As with "ingredients" (appendix 1), food labelling legislation grants a few, limited exemptions from declaration of the presence of additives in food, the principal ones of relevance to the GM debate being:

- processing aids (as defined)
- substances used to facilitate storage, sale, standardization, dilution or dissolution of an additive / additives, providing the use is no more than necessary.

Recent changes to labelling rules, however, over-ride these exemptions and now require allergenic derivatives of soy to be identified on the label, whatever their purpose or level in the food, unless they have been granted specific exemption. Thus, all protein derivatives and products of these will need to be declared but refined oils and their derivatives, if used in a way that is eligible for the original exemption, will remain exempt.

[34] Council Directive 89/107/EEC on the approximation of the laws of the Member States concerning food additives authorized for use in foodstuffs intended for human consumption.

[35] **'processing aid'** means any substance not consumed as a food ingredient by itself, intentionally used in the processing of raw materials, foods or their ingredients, to fulfil a certain technological purpose during treatment or processing and which may result in the unintentional but technically unavoidable presence of residues of the substance or its derivatives in the final product, provided that these residues do not present any health risk and do not have any technological effect on the finished product.

A2.1 Additives separated from crop oils

E322: Lecithin

Commercial lecithin is derived primarily from soy (although lesser quality material is also obtained from rapeseed, maize, sunflower and peanuts). Very limited, and expensive, alternatives can be obtained from egg yolk (almost entirely for pharmaceutical use), and, in theory, from animal (brain) fat (in practice unacceptable due to BSE).

Basic lecithin comprises a mixture of phospholipids and is not soluble in water. It is refined / fractionated / modified to different degrees according to intended end-use. For example, it can be made more water-dispersible by enzymic hydrolysis / alcohol fractionation and thus become suitable for a wide range of applications (still classified as E322). The alcohol-soluble / insoluble fractions act as oil-in-water / water-in-oil emulsifiers, respectively. *[Chemical modification is possible but is generally not permitted for food use.]*

It is widely used as an emulsifier in chocolate, ice-cream, margarine and mayonnaise and is also finding increased applications in ready meals and meat products.

In ***chocolate***, it helps reduce the viscosity of molten chocolate during processing, so improving its fluidity and enabling thinner, and better-defined, coatings and chocolate bars. It prevents crystals forming when chocolate is stored at elevated temperatures ("blooming") and helps chocolate set where water is present e.g. chocolate-coated ice creams.

It stabilises the fat / water emulsions in ***margarine and fat spreads***, thus improving their spreadability. It also prevents water leakage, avoiding spitting, when frying. Plain lecithin is used in spreads containing >80% fat; hydrolysed lecithin when the fat content is between 60% – 80%; it tends to be replaced by E471 in spreads with less than 60% fat.

In ***bread and bakery products***, it improves the crumb structure and contributes anti-staling properties, thereby extending shelf life. Soy lecithin has similar binding properties to egg yolk lecithin and is used to replace eggs in many products.

It is used in ***"instantised" powder*** mixes to enable them to disperse quickly and easily in milk or water.

Lecithin also acts as a synergist to antioxidants in fats and oils, and is often used in combination with them, e.g. to protect beta-carotene (Vitamin A).

As indicated in the analysis in the body of the report, usage levels are not high – typically ~0.3% – 0.5% in chocolate, dairy and "instantised" products.

E442: ammonium phosphatides, emulsifier YN

This group of additives comprises a mixture of ammonium salts of phosphorylated glycerides, which may be manufactured either synthetically or derived from a mixture of glycerol and partially hardened rapeseed oil.

They are used mainly as an emulsifier, reducing the surface tension of water to allow better combination of oils, fats and water, and as a stabiliser to prevent separation.

Typical applications are similar to lecithin and E442 is used particularly in chocolate products. However, it should be noted that it is not a direct substitute for lecithin in chocolate manufacture.

E442 has weaker properties than lecithin as an antioxidant.

E476: PGPR (polyglycerol polyricinoleates)

This is produced from castor oil and glycerol esters. It is a possible alternative, but not a direct substitute for lecithin in certain products and is sometimes used in conjunction with it. It helps reduce the viscosity of molten chocolate, enabling thinner coatings and better-moulded products, and also helps chocolate set where water is present e.g. chocolate-coated ice creams. It may be used together with lecithin in some applications but is much more difficult to control.

It is mainly used in icings, toppings and in cake mixes (to control fat crystallisation) but also in spreadable, reduced-fat products and salad dressings.

A2.2 Additives derived from fats and fatty acids

Fatty acids are natural elements of all fats and oils and are derived from them either during refining or by subsequent processing. Fatty acids derived from a range of vegetable oils are reacted, either directly with acids or via enzymatic modification, to produce a number of specialist emulsifiers, used in virtually every sector of the food industry.

The following derivatives of fatty acids may be derived from a number of plant oils, such as soy, maize and rapeseed, which may have been derived from GM crops. *[Some may be derived from animal fats.]*

E470a: sodium, potassium and calcium salts of fatty acids

These are a range of compounds of single or mixed solid organic acids obtained from edible sources, such as stearates and palmitates. They are generally used as a solid-phase lubricant that reduces friction between particles of the substance to which it is added – i.e. as a flow agent (anti-dusting agent), for example in dry, flour based ingredients such as cake mixes and bread / flour improvers. They act by complexing proteins and starch. Their mild emulsifying properties also facilitate dough handling.

E470a is also used as a mould release agent during the manufacture of confectionery (at about 50ppm) and in oven ready chips.

The anti-dusting property is of value from a health and safety angle in those cases where airborne dust may be an explosion hazard or the presence of certain enzymes may present a potential risk to workers handling the product.

E470b: magnesium salts of fatty acids

E470b has similar properties and uses to E470a and is used as an anti-caking agent in certain food supplement tablets and capsules.

E471: mono- and diglycerides of fatty acids

Manufactured from glycerine (E422) and fatty acids, and normally obtained from hydrogenated soybean oil.

Used where the foaming power of egg protein needs to be retained in the presence of fat and in baked goods as an 'anti-staling' agent where it prevents the loss of water from starches.

One of the most commonly used emulsifiers in the food processing industry. It is used in flour confectionery such as cakes / cake mixes, instant drink powders and dessert mixes, aerosol creams, extruded cereal-based products such as shaped snackfoods, dessert toppings, dehydrated potato, sterilised, pasteurised and UHT cream and cream substitutes, margarine and low fat spreads (<60% fat, in particular), and ice cream.

E472a: acetic acid esters of mono- and diglycerides of fatty acids

These are also known as acetoglycerides, acetylated mono and diglycerides and are produced by reacting esters of glycerol with edible fats and acetic acid. E472a improves aeration properties of high fat recipes; produces stable foam in whipped products; forms thin, flexible films as coating for meat products, nuts and fruits to improves appearance and extend shelf life. It is also used in bread, dessert toppings, cheese cake and mousse-type products.

E472b: lactic acid esters of mono- and diglycerides of fatty acids

E 472b is also known as “lactoglycerides”.

It is widely used to control emulsion stability, texture and viscosity in low-fat spreads, ice cream and mousse-type desserts, in starch-based foods such as macaroni, noodles, potato products, peanut butter and in the bakery industry.

E472c: citric acid esters of mono and diglycerides of fatty acids

E472c is used as an emulsifier / stabiliser in fats, bakery products and whipped toppings, and can be used as a substitute for lecithin in applications that require emulsifiers with high HLB value (all the E472 series of emulsifiers have this property).

It is allowed in infant formula and follow-on milk and other foods for infants and young children, where it is of particular value in products which contain partially or extensively hydrolysed proteins and a relatively high fat content.

E472e: mono and diacetyl tartaric acid esters of mono and diglycerides of fatty acids

Colloquially referred to as “datems” E472e are manufactured by the reaction of E471 (above) either with diacetyltartaric anhydride in the presence of acetic acid, or with acetic anhydride in the presence of tartaric acid.

Datems are widely used as a dough conditioner in yeast raised bakery products such as bread and also in instant drink mixes, gravy granules and frozen pizza.

E472f: mixed acetic and tartaric acid esters of mono and diglycerides of fatty acids

These are used to a limited extent in processed bread and some other products.

E473: sucrose esters of edible fatty acids

E473 is used to stabilise fat emulsions in margarine, mayonnaise, soups, dairy desserts / mixes and drinks containing dairy ingredients, and to modify starch in noodles and baked cereal products. It is also used as a texturiser in chewing gum and in surimi-type seafood analogues, and can also be used in protective coatings applied to fresh fruits to retard ripening and protect against spoiling.

E474: sucroglycerides
Sucroglycerides are produced by reacting sugar with edible oil / fat to produce a mixture of mono and di-esters of sucrose and fatty acids, together with mono-, di- and triglycerides from the oil / fat.

E474 is widely used in almost every food and beverage sector as an emulsifier, stabiliser and thickener. Typical examples include egg- cereal- and starch-based desserts, dairy-based drinks, yoghurts, ice cream and sorbets, a wide range of infant and dietetic foods and food supplements, beverage whiteners, surface treated fresh fruit, cocoa mixes (powders and syrups), soups and broths, sauces, meat products and chewing gum.

Applications also include use as a texturiser in biscuit mixes, and as an emulsifier in baked goods and baking mixes, dairy product analogues, frozen dairy desserts and mixes, and whipped milk products. The maximum estimated content of sucroglycerides in these uses is 1.5%.

E475: polyglycerol esters of fatty acids
E 475 acts as a wetting agent, to aid powder dispersion and as a thickener. It is used in a wide range of foods such as toppings and cake mixes, ice cream, desserts, bakery and pastry products, chewing gum, coffee whitener, yellow fat spreads, baby milk powder and milk powders in which the dairy fat has been replaced with vegetable fats.

E477: propylene glycol esters of fatty acids
E477 is mainly used in cakes & whipped toppings as emulsifiers and aerating agents.

E479b: thermally oxidized soybean oil interacted with mono and diglycerides of fatty acids
E479b is used in margarine and similar fat emulsions specially formulated for frying purposes.

A2.3 Thickeners and stabilisers

E415: xanthan gum
Xanthan gum is produced by fermenting glucose with *Xanthomonas campestris* using soya and glucose / glucose syrup as sources of nitrogen and carbohydrate respectively. It is used as an emulsifier, lubricant, suspending agent and thickener / gelling agent, and is particularly effective in acid systems.

It is used in both foods and animal feeds. Typical applications include:

- salad dressings, tomato ketchup, mayonnaise, coleslaw, mustard etc
- bakery fillings, desserts, cake mixes, toppings, egg white replacers, gluten-free bread
- chocolate sauce, chocolate drink, instant drinks
- sauces, instant soups, pizza sauces
- sweet relish
- batter mixes
- ice cream, sorbets, ice lollies, tiramisu

- fruit juice, fruit preparations
- chewing gum
- creamed cottage cheese, yogurt milk shake, yogurt
- fat reduced margarine

E460: cellulose
Cellulose is derived from the structural framework of plant cell walls. E460 is principally obtained from wood pulp but may also be from cotton. There is also a form of cellulose obtained from bacteria (*Acetobacter xylinum*).

Cellulose has many uses as an anti-caking agent, emulsifier, stabilizer, dispersing agent, thickener, and gelling agent but these are generally subsidiary to its most important use of holding on to water.

Water cannot penetrate crystalline cellulose but the structure of dry, amorphous cellulose is capable of absorbing and retaining significant quantities of water in a form that protects the food against ice crystal damage during freezing.

Cellulose gives improved volume and texture particularly as a fat replacer in sauces and dressings but its insolubility means that all products will be cloudy.

E461: methyl cellulose
Methylcellulose is a chemical modification of the cellulose, obtained from the press cake produced during cotton processing.

Methylcellulose and other cellulose derivatives (E 463 - 466) are obtained from cellulose. In contrast to the cellulose these pour in water.

Cellulose ethers are used to add consistency, texture, mouthfeel and colour, in particular to baked goods, ice cream, savoury dressings and desserts.

E463: hydroxypropyl cellulose
E463 is principally used as a non-thixotropic thickener in whipped toppings, confectionery, sterilised / pasteurised / UHT cream and cream substitutes. It also produces edible films.

E464: hydroxypropyl methyl cellulose
E464 is used in similar applications to E463 and also in bakery and low-fat products.

E465: ethyl methyl cellulose
E465 is used in a range of foods as a thickener, emulsifier, stabiliser and foaming agent, e.g. sterilised / pasteurised / UHT cream and cream substitutes.

E466: carboxy methylcellulose; Sodium carboxy methylcellulose
Carboxy methylcellulose (CMC; E466) is a derivative of cellulose formed by its reaction with alkali and chloroacetic acid. It is not a single chemical compound, and its properties vary according to its composition, average chain length and degree of substitution.

It dissolves rapidly in cold water and is mainly used for controlling viscosity, without gel formation, even in the presence of calcium (e.g. in milk-based systems). Its viscosity drops during heating, and it is therefore used to improve the volume of baked products by encouraging gas bubble formation. Its control of viscosity enables its use as a thickener, emulsion stabilizer (e.g. with milk casein) and suspending agent.

CMC has strong water-binding capacity, even at low viscosity, and it therefore plays a role in retarding staling of baked goods and reducing fat uptake into fried foods.

A thixotropic grade is available, which is an economical replacement for xanthan gum in applications such as dressings, ketchup and sauces, which become fluid when shaken and solidify again on standing.

E468: crosslinked sodium carboxy methyl cellulose

E469: enzymatically hydrolysed carboxy methyl cellulose
E469 is the sodium salt of CMC which has been partially-hydrolysed by enzymatic treatment with a cellulase from *Trichoderma reesei*. It is used as a carrier, glazing agent, stabiliser and thickener.

A2.4 Modified starches

Although chemically-modified starches have been assigned "E numbers", they may be designated on labels simply as "modified starch" without indicating their origin or the type of chemical modification. As with the natural starches described in Appendix 1, the base materials may be derived from a variety of cereal crops and the individual modified starches are, to a certain extent, interchangeable as to their source material.

Care must also be taken to distinguish between modified starches derived from "waxy" maize and others.

Modified starches are widely used in virtually every food sector, with the specific starch being selected on the basis of the desired texture and heating / chilling / freezing characteristics required in the individual food system, its acidity and other properties. Selected examples are given below.

E1412 (di-starch phosphate)
E1412 is a versatile thickener widely used in systems which undergo moderate processing conditions, such as bakery fillings and toppings, canned foods, soups, sauces and gravies, fruit fillings (fresh and canned) and baby foods.

E1420 acetylated starch
E1422 acetylated di-starch adipate
Acetylated starch (E1420) is produced by reacting basic starch, generally from maize, potatoes or wheat, with acetic acid. Acetylated starch may be further reacted with adipic acid to yield in acetylated distarch adipate (E1422). Acetylated starches are characterised by high shear strength and are particularly stable against heat and acids. They are stable when subjected to prolonged heating, possess good cold storage and freeze-thaw stability, and are capable of forming thin, flexible, water-soluble films.

These starches are widely used as binders and thickeners in
- chilled and frozen products, such as gateaux, cakes, fish/meat/poultry and vegetable ready meals, pizza etc
- canned foods
- sauces, dressings and mayonnaise-type products

- sweets and desserts
- baked goods and flour confectionery

E 1442 (hydroxypropyl di-starch phosphate)
E1442 hydrates rapidly to generate very high viscosity without cooking. It possesses excellent cold storage and freeze-thaw stability, and retains moisture / extends shelf life of baked products.

A comprehensive listing of all natural and modified starches is available from the International Starch Institute in Denmark, and is reproduced below:

E-Number	INS-number[3]	Name	Function (CCFAC)[3]
	1400[1]	Dextrins, white and yellow	Stabilizer, thickener, binder
	1401[1]	Acid treated starch	Stabilizer, thickener, binder
	1402[1]	Alkaline modified starch	Stabilizer, thickener, binder
	1403[1]	Bleached starch	Stabilizer, thickener, binder
E1404[2]	1404	Oxidized starch	Emulsifier, thickener, binder
	1405[1]	Enzyme treated starch	Thickener
E1410[2]	1410	Monostarch phosphate	Stabilizer, thickener, binder
	1411	Distarch glycerol	Stabilizer, thickener, binder
E1412[2]	1412	Distarch phosphate	Stabilizer, thickener, binder
E1413[2]	1413	Phosphated distarch phosphate	Stabilizer, thickener, binder
E1414[2]	1414	Acetylated distarch phosphate	Emulsifier, thickener
E1420[2]	1420	Acetylated starch, mono starch acetate	Stabilizer, thickener
	1421	Acetylated starch, mono starch acetate	Stabilizer, thickener
E1422[2]	1422	Acetylated distarch adipate	Stabilizer, thickener, binder
	1423	Acetylated distarch glycerol	Stabilizer, thickener
E1440[2]	1440	Hydroxypropyl starch	Emulsifier, thickener, binder
E1442[2]	1442	Hydroxypropyl distarch phosphate	Stabilizer, thickener
	1443	Hydroxypropyl distarch glycerol	Stabilizer, thickener
E1450[2]	1450	Starch sodium octenyl succinate	Stabilizer, thickener, binder, emulsifier, encapsulant
E1451[2]		Acetylated oxidised starch	

[1]) Dextrin, bleached starch, starches modified by acid, alkali and enzyme or by physically treatment are not considered as food additives in the context of the EEC Directive 95/2/EC.
[2]) Modified starches, Annex 1 of EEC Directive No. 95/2/EC
[3]) CCFAC International Numbering System (INS) 1989

A2.5 Antioxidants

Antioxidants function by preventing the deterioration of fats by oxidation (rancidity) and are thus distinct from “preservatives” which prevent microbiological growth and consequent deterioration of food.

E300/E301/E302: ascorbic acid (vitamin C)/sodium ascorbate/calcium ascorbate)
E304(i) ascorbyl palmitate
E304(ii) ascorbyl stearate (fatty acid esters of ascorbic acid)

Ascorbic acid can be manufactured commercially by several different methods, including fermentation of glucose using GM bacteria. Thus, both substrate and organism used can be GM. The conventional synthesis involved a complex, six-stage process, including a fermentation step. Although the micro-organism used was, historically, non-GM (Acetobacter), the glucose substrate may be GM-derived outside the EU, using GM-derived enzymes.

More recently, a new two-stage process, using GM micro-organisms (*Erwinia* species) has been developed. It is also believed that ascorbic acid is produced directly by GMM fermentation in Asia (a major supplier) but precise details are confidential.

Ascorbic acid and its water-soluble sodium and (occasionally) calcium salts are commonly added to a wide range of foods as antioxidants and colour stabilisers. The fat-soluble esters of ascorbic acid with long-chain fatty acids (E304) are used to protect fats from oxidation. Ascorbic acid performs different technical functions and is widely used in many food sectors, including:

- antioxidant in comminuted meat products such as sausages and sliced meats
- to help maintain the appearance of cured meats, such as ham, pâté, frankfurters etc where it stabilises the pink colour obtained from the nitrite used as the curing salt and is also believed to help prevent the production of nitrosamine – a potent carcinogen – in the stomach
- to improve the shelf life of beers and prevent haze development
- a flour improving agent in a range of baked foods where it helps the handling properties of the raw dough and also aeration and crumb structure in the finished product
- to inhibit discolouration in cut fruits, fruit pulp and juices (prevents oxidative browning)
- in butter, breakfast cereals, frozen egg products, powdered and concentrated milk, frozen potatoes, tinned baby foods and wine

One form of ascorbic acid (the L- enantiomer) is vitamin C and is frequently added to products that may lose vitamin C in processing - such as dried potatoes.

Ascorbyl palmitate is frequently used in combination with the alpha-tocopherols E306 and E307 due to their synergistic antioxidant properties.

E306 / E307 Tocopherols

Tocopherols are a group of compounds extracted by vacuum distillation from maize, soya, cottonseed, rice germ or wheat germ oils.

They are fat-soluble and function both as antioxidants and also as a source of vitamin E for food fortification. Alpha-tocopherol has the highest vitamin E activity, whilst delta-tocopherol exhibits the greatest antioxidant effect.

E306 is used in meat products, dessert toppings and vegetable oils as well as a vitamin supplement. It also protects other nutrients, such as vitamin A, from oxidation but is largely destroyed by freezing.

It acts as an antioxidant synergistically with ascorbyl palmitate and is frequently, therefore, used in combination with E304.

A2.6 Acids; acidity regulators

E330 citric acid / E331 sodium citrate

Although citric acid occurs widely in nature (e.g. citrus fruits such as lemons), it is produced commercially by fermentation; sodium citrate is obtained by neutralising the acid. The fermentation substrates can include glucose derived from maize starch (GM origin and GM enzymes used in production); a GMM (based on *Aspergillus niger*) may also be used.

Citric acid is widely used in many foods for a range of properties.

- a synergist, enhance the effectiveness of other antioxidants in retaining colour and flavour;
- flavouring, to impart “lemon” flavour to a wide range of products such as soft drinks, confectionery, desserts;
- a sequestrant in foods, combining with trace metals to prevent discolouration (e.g. it combines with iron in wine to prevent cloudiness);
- to reduce excess sugar loss from germinated barley in brewing;
- to create an acidic environment to discourage growth of certain bacteria, yeasts and moulds;
- an acid, *per se*, e.g. in raising agents for baked goods;
- antioxidant in meat products

Because of this range of functions, it is used in a wide range of products such as alcoholic and non-alcoholic drinks, bakery products, cheese and dairy products, biscuits, cake mixes, frozen fish, ice cream, jams, jellies, frozen potato products, sorbets, packet soups, sweets, tinned fruits, sauces and prepared vegetables.

Sodium citrate is used as an acidity regulator.

E574 gluconic acid
E575 glucono-deltalactone
E579 ferrous gluconate

Gluconic acid is produced by the reduction of glucose either by direct fermentation or using the enzyme glucose oxidase. Gluconic acid, its salts and glucono-delta-lactone are used in several food categories as acidity regulators, chelating (metal-binding) agents, colour stabilisers and, to a lesser extent, as antioxidants.

Glucono-delta-lactone hydrolyses progressively to gluconic acid when in the presence of water, slowly at room temperature but rising steadily with increasing temperature. This allows complete control over such aspects as dough rising (in conjunction with bicarbonate) or meat fermentation.

This group of additives are therefore typically used in

- Dried, fermented meat and fish products such as salami and marinated herrings (maatjes), where its acidity control during the early stages of production allows the desired micro-organisms to develop, whilst retarding the growth of potential food poisoning organisms;
- Soft drinks (acid);
- A firming agent in canned vegetables (binding with calcium);

- Chelating agent in preserved fruit and vegetables, where it helps retain colour, retain vitamins and, in some cases, to retard fat rancidity (e.g. in canned black olives)
- In baking powders / raising agents to control the rate of release of carbon dioxide to produce uniform crumb structures

As an example of international implications of the use of GM derivatives, *Ferrous Gluconate* was recently reported under the EU RASFF system to have been detected in black beans from USA imported into Slovenia. Ferrous gluconate is also used as an iron supplement.

A2.7 Colours

E150a plain caramel
E150b caustic sulphite caramel
E150c ammonia caramel
E150d sulphite ammonia caramel
A range of caramels are produced by the controlled heat treatment of sucrose (sugar beet / cane) or glucose, derived from hydrolysed maize starch, with or without the presence of ammonia or sulphur dioxide. The shade and intensity of caramels range from dark brown to black. Caramels and are widely used in many food categories and the appropriate type of caramel for a given application is determined by factors such as acidity and composition of the food or drink:

- beer, stouts and spirits
- soft drinks, particularly cola drinks,
- flour based confectionery, buns, biscuits, doughnuts
- coatings, decorations, fillings and toppings,
- dessert mixes, dairy desserts, frozen desserts, ice cream
- fish and shellfish spreads
- gravy browning, pickles, sauces and dressings
- confectionery
- vinegar.

There are two elements of potential interest with respect to the involvement of GM: the origin of the starch (e.g. maize) from which the glucose has been obtained and the use of GM-derived enzymes in the production of the glucose (e.g. amylase, glucose isomerase and pullulanase).

E160a β-carotene
Carotenes are a group of natural colouring materials that occur widely in, and historically were extracted from plant materials. However, β-Carotene is now largely produced by fermentation of glucose, although the extent to which this involves GMMs (such as GM *Erwinia herbicola*) is kept confidential. Some production in Taiwan has been certified by a European certification body as non-GM. There are also reports that *Annatto* may now be produced in this manner, although it is more usually extracted from tree seeds.

Beta-carotene also possesses anti-oxidant properties and, in addition to its long-established role as a precursor to vitamin A, is being promoted for health-related effects ("free radical scrounger").

Beta-carotene is insoluble in water and is therefore supplied in different forms, according to the intended application, in a wide variety of foods and drinks:

- Oily suspensions (in various concentrations) for products such as margarine, salad dressing, popcorn, and vitamin A capsules;
- Cold water dispersible powders for dairy products, soft drinks, bakery products, custards and desserts, ice creams, instant beverages and nutritional powders;
- Emulsions, primarily for beverages and other water based products.

A2.8 Flavour enhancers

E620 Glutamic acid
E621 Monosodium Glutamate (MSG)
Other glutamate salts (E621 - E625)
Glutamic acid and its salts – the most widely used by far being MSG – may be produced by one of two processes. Historically, it was separated from the hydrolysis of vegetable protein products. The sodium salt of glutamic acid, MSG, was also extracted from seaweed or fermented from molasses or sugar beet.

More recently, it is derived commercially by direct fermentation.

A major source of MSG is Japan and, although the technical details are closely guarded, it is commonly assumed that the micro-organisms used for the fermentation process are GM (*Corynebacterium glutamicus*). As with all fermentation processes the energy nutrient substrate is derived from glucose / starch, from maize and other similar crops.

The principle role of MSG is as a flavour enhancer in a very wide range of savoury products, where it reinforces the savoury taste whilst, at the same time suppressing any bitter notes, and can give a perception of "saltiness" in the presence of reduced levels of salt.

It is frequently used in combination with ribotides, inosinates and guanylates with which it acts synergistically to produce a more rounded, fuller flavour in almost all classes of savoury foods such as:

- Soups, sauces, gravies and bouillons
- Ready meals based on fish, meat, poultry, cheese and vegetables
- Snack foods

E626 – E635 inosinates, guanylates and ribotides
This category of flavour enhancers are widely used in savoury products, where they act synergistically with MSG. They are normally supplied as co-crystallised mixtures with MSG, in the proportions reflecting their optimal synergism. They are potentially derived from fermentation but information on the commercial processes is not easily available.

A2.9 Miscellaneous additives

E921: cystine/cysteine

Although present in many vegetable proteins and in certain animal tissues, cystine (or the closely related cysteine) can be produced by fermentation of glucose using GM bacteria (E. coli).

Cysteine is widely used in the baking industry as a “flour treatment agent”, to accelerate dough development during commercial plant-scale bread baking. It is also added to dietary preparations and animal feeds.

It is also one of the amino acids that are used as a starting material for the production of savoury, “roast type” flavourings via the so-called Maillard reaction, whereby it is reacted with a reducing sugar such as glucose. These flavourings are widely used in foods such as all types of meat-based meals, snacks and crisps but their properties can be adjusted by varying the production process and subsequent blending to produce flavours that range from mild, fish-like to rich game.

E951 aspartame

Aspartame is a low-calorie sweetener, formed from the two amino-acids asparagine acid and phenylalanine. Phenylalanine can be made by fermentation using either GMM (E. coli) or conventional micro-organisms.

It is used in a very wide range of foods and drinks, and is also available as a retail table-top sweetener in powder or mini-tablet form.

It is typically used in

- diet and other soft drinks
- sugar-free confectionery
- dairy and other desserts, fruit-based yoghurts
- sauces and salad dressings
- chewing gum

A2.10 Flavourings

Several thousand “flavourings” are available for food use, ranging from extracts from natural products through so-called “nature-identical” to synthetic materials. Many commercial products are themselves complex (and confidential) blends of numerous ingredients. Their use is widespread across all food and beverage sectors.

Production technology similarly spans many areas, some of which will involve raw materials and / or micro-organisms that have been subject to genetic modification, and is summarised very briefly:

- Micro-organisms: no details of the commercial use of GMMs are currently available, although several potential processes are known to exist
- Nutrients on which commercial micro-organisms are grown will include glucose and other energy sources that potentially have been derived from GM maize. Some micro-organisms are grown on protein substrates derived from soy.

- Certain classes of flavours are produced by enzymic conversion of natural materials
    - Meat-like flavours from plant and yeast raw materials using lipases and proteases
    - Cheese and dairy flavours by enzymic modification of milk fat and protein (lipase and protease)
    - Fruit flavours derived from plant cells by enzymic cleavage (pectinases)
    - In all the above, the precise details are commercially protected but it is known that lipases, proteases and pectinases are available from GM sources
- Proteins (including from soy), amino acids and reducing sugars (such as glucose and fructose) are heated under pressure to produce Maillard flavours that simulate a range of savoury flavours such as fish and meats
- Fats and fatty acids (soy, rape etc and animal) are modified or combined chemically with alcohols etc
- Vegetable proteins (particularly soy) are the basis for the enzymic production of glutamic acid and MSG (E620 and E621, respectively) and the more intense flavour enhancers, inosinates / guanylates and ribotides (E626 – E635 series).

Because of the intense properties of many flavours, particularly synthetics, they are commonly dispersed on carriers such as starch, maltodextrin and flours and, in the case where they are liquid or have to be dispersed into a liquid food medium, they may be supplied in either dissolved or emulsified form.

Diacetyl

Diacetyl is the principal component of synthetic, typical butter flavours and is produced by non-GM fermentation from citric acid or glucose (which may be derived from / using GM maize and / or enzymes). It is used as a component in flavourings added primarily to yellow fat spreads and flour confectionery.

Appendix 3: Enzymes potentially derived from GM origins

Principal enzymatic activity	Host organism	Donor organism	Application examples	
	(Production organism)		Food (* Key below)	Feed
Acetolactate decarboxylase (alpha)	*Bacillus amyloliquefaciens or subtilis*	*Bacillus sp.*	Beverages	
	Saccharomyces cerevisiae	*Enterobacter sp.*	Beverages	
Aminoacylase	*Aspergillus melleus*	*none*	Diet	
Aminopeptidase	*Aspergillus niger*	*none*	Cheese	
	Aspergillus oryzae	*none*	Beverages Cheese Egg Fish Meat Milk Soup Spice	
	Lactococcus lactis	*none*	Cheese Milk	
	Rhizopus oryzae	*none*	Egg Cheese Fish Meat Milk Soup Spice	
	Trichoderma reesei or longibrachiatum	*Aspergillus sp.*	Cheese Egg Meat Milk Spice	Feed
AMP deaminase	*Aspergillus melleus*	*none*	Soup Spice	
Amylase (alpha)	*Aspergillus niger*	*none*	Bakery Beverages Diet Fruit Starch/cereals	Piglet
	Aspergillus niger var. awamori	*none*	Beverages Fruit Starch/cereals	
	Aspergillus oryzae	*none*	Bakery Beverages Diet Fruit Starch/cereals	Chicken rearing
	Bacillus amyloliquefaciens or subtilis	*Bacillus sp.*	Bakery Beverages Starch/cereals	Piglet. Pig rearing. Sow
		Thermoactinomyces sp.	Bakery	Feed
		none	Bakery Beverages Fruit Starch/cereals	Feed
	Bacillus licheniformis	*Bacillus sp.*	Beverages Starch/cereals Sugar	
		none	Beverages Starch/cereals	
	Bacillus stearothermophilus	*none*	Bakery	
	Microbacterium imperiale	*none*	Bakery Confectionery Sugar	
	Thermomonospora viridis	*none*	Starch/cereals Sugar	
Amylase (beta)	*Barley*	*none*	Bakery Beverages Diet Fruit Starch/cereals	
	Soy	*none*	Bakery Beverages Fruit Starch/cereals	
Arabinanase	*Aspergillus niger*	*none*	Beverages Choc	Feed
Arabino-furanosidase	*Aspergillus niger*	*Aspergillus sp.*	Beverages	
		none	Bakery Beverages Choc	

Catalase	*Aspergillus niger*	*Aspergillus sp.*	Bakery Beverages Cheese Egg Fats Starch/cereals Sugar	
		none	Cheese Milk	
Cellulase	*Aspergillus niger*	*none*	Bakery Beverages Diet Fruit Starch/cereals	
	Penicillium or Talaromyces emersonii	*none*	Beverages Starch/cereals	Feed
	Penicillium funiculosum	*none*	Beverages Starch/cereals	Feed
	Trichoderma reesei or longibrachiatum	*Trichoderma sp.*	Beverages	Feed
		none	Bakery Beverages Choc Diet Fruit Starch/cereals	Feed
	Trichoderma viride	*none*	Beverages Fruit	
Cyclodextrin glucano-transferase	*Bacillus licheniformis*	*Thermoanaerobacter sp.*	Starch/cereals	
	Bacillus macerans	*none*	Fruit Starch Sugar	
Dextranase	*Chaetomium erraticum*	*none*	Sugar	
	Penicillum lilacinum	*none*	Starch/cereals	
Esterase	*Rhizomucor miehei*	*none*	Cheese	
Galacto-mannanase	*Aspergillus niger*	none	Bakery Beverages	Feed
Galactosidase (alpha)	*Aspergillus niger*	*none*	Diet Starch/cereals Sugar	
	Saccharomyces cerevisiae	*Guar plant*	Beverages	Feed
Glucanase (beta)	*Aspergillus aculeatus*	*none*	Beverages Starch/cereals	Piglet. Chicken rearing.
	Aspergillus niger	*none*	Bakery Beverages Starch/cereals	Piglet. Laying hens. Chicken /turkey rearing.
	Bacillus amyloliquefaciens or subtilis	*Bacillus sp.*	Beverages	feed
		none	Beverages	feed
	Disporotrichum dimorphosporum	*none*	Beverages	
	Humicola insolens	*none*	Beverages Starch/cereals	Pig and Chicken rearing. Piglet
Glucanase (beta)	*Penicillium or Talaromyces emersonii*	*none*	Beverages Starch/cereals	Feed
	Penicillium funiculosum	*none*	Beverages Starch/cereals	Chicken /turkey/ pig rearing. Laying hens.
	Penicillium multicolor	*none*	Beverages Choc Fruit Soup Spice	
	Pseudomonas paucimobilis	*none*	Soup Spice	

	Trichoderma reesei or longibrachiatum	*Trichoderma sp.*	Starch/cereals	Chicken /turkey rearing. Piglet. Laying hens.
		none	Bakery Beverages Starch/cereals	Feed
Glucoamylase or Amylo-glucosidase	*Aspergillus niger*	*Aspergillus sp.*	Beverages Fruit Starch/cereals	
		Talaromyces sp.	Starch/cereals	
		none	Bakery Beverages Fruit Starch/cereals	
	Rhizopus delemar	*none*	Bakery Beverages Starch/cereals	
	Rhizopus niveus	*none*	Bakery Beverages Starch/cereals	
	Rhizopus oryzae	*none*	Bakery Beverages Starch/cereals	
Glucose isomerase	*Actinoplanes missouriensis*	*none*	Starch/cereals	
	Streptomyces lividans	*Actinoplanes sp.*	Starch/cereals	
	Streptomyces murinus	*none*	Starch/cereals	
	Streptomyces olivochromogenes	*none*	Starch/cereals	
	Streptomyces rubiginosus	*Streptomyces sp.*	Starch/cereals	
Glucose oxidase	*Aspergillus niger*	*Aspergillus sp.*	Bakery Cheese Egg Milk	
		none	Bakery Beverages Egg	
	Aspergillus oryzae	*Aspergillus sp.*	Bake	
	Penicillium chrysogenum	*none*	Bakery Beverages Egg	
Glucosidase (alpha)	*Aspergillus niger*	*none*	Beverages Starch/cereals	
Glucosidase (beta)	*Aspergillus niger*	*none*	Beverages Starch/cereals	Feed
	Penicillium decumbens	*none*	Beverages Fruit	
Glucosidase (exo-1,3-beta)	*Trichoderma harzianum*	*none*	Beverages	
	Penicillium funiculosum	*none*	Beverages	
Glucosyl-transferase or Trans-glucosidase	*Aspergillus foetidus*	*none*	Starch/cereals	
Glutaminase	*Bacillus subtilis*	*none*	Cheese Fish Meat Soup Spice	
Hemicellulase	*Aspergillus foetidus*	*none*	Bakery Starch/cereals	Feed
	Aspergillus niger	*none*	Bakery Beverages Fruit	Feed
	Bacillus amyloliquefaciens or subtilis	*Bacillus sp.*	Bakery Starch/cereals	Feed
		none	Bake	
Hexose oxidase	*Hansenula polymorpha*	*Chordrus sp.*	Bakery Cheese Fats Milk Soup	

			Starch/cereals	
Inulase	*Aspergillus oryzae*	*Aspergillus sp.*	Starch/cereals	
	Aspergillus niger	*none*	Starch/cereals	
Invertase or Fructo-furanosidase (beta)	*Saccharomyces cerevisiae*	*none*	Beverages Confectionery Sugar	Feed
Laccase	*Aspergillus oryzae*	*Myceliopthora sp.*	Beverages	
		Polyporus sp.	Beverages	
	Trametes versicolor	*none*	Beverages	
Lactase or Galactosidase (beta)	*Aspergillus oryzae*	*Aspergillus sp.*	Cheese Diet Ice Milk	
		none	Cheese Diet Ice Milk	
	Kluyveromyces lactis	*Kluyveromyces sp.*	Ice Milk	
		none	Cheese Diet Ice Milk	
Lipase, monoacyl-glycerol	*Penicillium camembertii*	*none*	Cheese Fats Milk Soup Spice	
Lipase, triacylglycerol	*Aspergillus niger*	*none*	Bakery Cheese Fats Milk Soup Spice	
	Aspergillus oryzae	*Candida sp.*	Fats	
Lipase, triacylglycerol	*Aspergillus oryzae*	*Fusarium sp.*	Bakery Fats	
		Rhizomucor sp.	Cheese Fats Spice	
		Thermomyces sp.	Bakery Fats	
	Calf gullets	*none*	Cheese Fats Milk Spice	
	Candida lipolytica	*none*	Bakery Cheese Fats Spice	
	Candida rugosa	*none*	Bakery Cheese Fats Milk Soup Spice	
	Goat gullets	*none*	Cheese Spice	
	Lamb gullets	*none*	Cheese Spice	
	Mucor javanicus	*none*	Bakery Cheese Egg Fats Milk Soup Spic	
	Penicillum roqueforti	*none*	Cheese Egg Fats Milk Soup Spice	
	Rhizomucor miehei	*none*	Cheese	
	Rhizopus delemar	*none*	Bakery Cheese Fats Milk Soup Spice	
	Rhizopus niveus	*none*	Bakery Cheese Choc Fats Milk Soup Spice	
	Rhizopus oryzae or arrhizus	*none*	Bakery Cheese Fats Milk Soup Spice	
Lipoxygenase	*E. coli*	*Pea*	Bakery Spice	
	soy flour		Bake	
Lysozyme	*Chicken egg*	*none*	Beverages Cheese Meat Milk Salad	

Maltogenic amylase	*Bacillus amyloliquefaciens or subtilis*	*Bacillus sp.*	Bakery Starch/cereals	
Mannanase (endo-1,4-beta)	*Aspergillus niger*	*none*	Bakery Beverages Fruit Starch/cereals	
	Trichoderma reesei or longibrachiatum	*Trichoderma sp.*	Starch/cereals	Feed
Pectin lyase	*Aspergillus japonicus*	*none*	Beverages Fruit	
	Aspergillus niger var. awamori	*Aspergillus sp.*	Beverages Choc Fruit	
	Aspergillus niger	*Aspergillus sp.*	Beverages Fruit	Feed
		none	Beverages Choc Fruit	Feed
	Aspergillus sojae	*none*	Beverages Fruit	
	Penicillium funiculosum	*none*	Beverages Fruit	
	Rhizopus oryzae	*none*	Beverages Fruit	
	Trichoderma reesei or longibrachiatum	*Aspergillus sp.*	Beverages Choc Fruit	Feed
Pectin methylesterase or Pectinesterase	*Aspergillus japonicus*	*none*	Beverages Fruit	
	Aspergillus niger	*Aspergillus sp.*	Beverages Choc Fruit	Feed
		none	Beverages Choc Fruit	Feed
	Aspergillus oryzae	*Aspergillus sp.*	Beverages Fruit	
	Aspergillus sojae	*none*	Beverages Fruit	
	Penicillium funiculosum	*none*	Beverages Fruit	
	Rhizopus oryzae	*none*	Beverages Fruit	
	Trichoderma reesei or longibrachiatum	*Aspergillus sp.*	Beverages Choc Fruit	
Pentosanase	*Aspergillus niger*	*none*	Bakery Beverages Fruit	
	Bacillus amyloliquefaciens or subtilis	*Bacillus sp.*	Bakery	
		none	Bakery	
	Humicola insolens	*none*	Bakery	
	Trichoderma reesei or longibrachiatum	*none*	Bakery Beverages Choc Starch/cereals	Feed
Phosphatase	*Aspergillus niger*	*none*	Beverages Egg	
Phospho-diesterase	*Leptographium procerum*	*none*	Spice	
	Penicillium citrinum	*none*	Soup Spice	
Phospholipase A	*Aspergillus oryzae*	*Fusarium sp.*	Bakery	
	Porcine pancreas	*none*	Egg Fats Fruit	
	Streptomyces vialoceoruber	*none*	Egg Fats	
	Trichoderma reesei or longibrachiatum	*Aspergillus sp.*	Bakery Fats	Feed
Phospholipase B	*Aspergillus niger*	*none*	Fats Starch/cereals	

	Aspergillus niger var. awamori	*none*	Bakery Starch/cereals	Feed
	Trichoderma reesei or longibrachiatum	*Aspergillus sp.*	Bakery Starch/cereals	Feed
Phytase	*Aspergillus niger*	*Aspergillus sp.*	Beverages Diet Starch/cereals	Feed
		none		
	Aspergillus oryzae	*Peniophora sp.*	Starch/cereals	Piglet. Pig rearing. Laying hens. Chicken rearing. Sows.
	Trichoderma reesei or longibrachiatum	*Aspergillus sp.*		Piglet. Pig rearing. Laying hens. Chicken rearing. Sows.
	Schizosaccharomyces pombe	*none*		Feed
Poly-galacturonase or Pectinase	*Aspergillus aculeatus*	*none*	Beverages Fruit	
	Aspergillus niger	*none*	Beverages Choc Fruit	Feed
		Aspergillus sp.	Beverages Choc Fruit	
	Aspergillus pulverulentus	*none*	Beverages Choc Fruit	
	Penicillium funiculosum	*none*	Beverages	
	Trichoderma reesei or longibrachiatum	*Aspergillus sp.*	Beverages Choc Fruit	Feed
Protease (incl. milkclotting enzymes)	*Actinida chinensis*	*none*	Diet Meat	
	Ananas comosus	*none*	Bakery Beverages Diet Fish Meat Spice	Feed
	Aspergillus melleus	*none*	Cheese Egg Diet Fish Meat Milk Soup Spice	
	Aspergillus niger	*none*	Bakery Beverages Diet Egg Fish Fruit Meat Soup Spice Starch/cereals	Feed
	Aspergillus niger var. awamori	*Calf stomach*	Cheese	
	Aspergillus oryzae	*Rhizomucor sp.*	Cheese Meat	
		none	Bakery Beverages Cheese Choc Egg Diet Fish Fruit Meat Milk Soup Spice Starch/cereals	Feed
	Aspergillus sojae	*none*	Fish Meat Milk Spice Starch/cereals	Feed
	Bacillus amyloliquefaciens or subtilis	*Bacillus sp.*	Bakery Beverages Cheese Fish Meat Milk Starch/cereals	Feed
		none	Bakery Beverages	Feed

			Cheese Fish Meat Soup Spice Starch/cereals	
	Bacillus licheniformis	*Bacillus sp.*	Fish Meat	
		none	Cheese Fish Meat Soup Spice	Feed
	Bacillus stearothermophilus	*none*	Egg Fish Meat Soup Spice	
	Bacillus thermoproteolyticus	*none*	Starch/cereals	
	Calf stomach	*none*	Cheese	
	Carica papaya	*none*	Bakery Beverages Diet Fish Meat Spice	Feed
	Cryphonectria or Endothia parasitica	*Cryphonectria sp.*	Cheese	
		none	Cheese	
	Ficus glabrata	*none*	Bakery Beverages Cheese Diet Fish Meat Spice	Feed
	Goat stomach	*none*	Cheese	
	Kiwi	*none*	Meat	
	Kluyveromyces lactis	*Calf stomach*	Cheese	
	Ox stomach	*none*	Cheese	
	Penicillium citrinum	*none*	Cheese Fish Fruit Meat Milk Soup Spice	
	Porcine pancreas	*none*	Cheese Diet Meat	
	Rhizomucor miehei	*none*	Cheese	
	Rhizopus niveus	*none*	Cheese Fish Fruit Meat Milk Soup Spice	
Pullulanase	*Bacillus acidopullulyticus*	*none*	Bakery Beverages Starch/cereals	
	Bacillus circulans	*none*	Beverages Starch/cereals Sugar	
	Bacillus licheniformis	*Bacillus sp.*	Starch/cereals	
	Bacillus subtilis	*Bacillus sp.*	Beverages Starch/cereals	
	Klebsiella planticola	*Klebsiella sp.*	Beverages Starch/cereals	
		none	Beverages Starch/cereals	Feed
	Trichoderma reesei or longibrachiatum	*Hormoconis sp.*	Bakery	
Rhamnosidase (alpha-L)	*Penicillium decumbens*	*none*	Beverages Fruit	Feed
	Penicillium multicolor	*none*	Beverages Choc Fruit Soup Spice	
Tannase	*Aspergillus niger*	*none*	Beverages Choc Fruit	
Trans-glutaminase	*Streptoverticillium mobaraense*	*none*	Bakery Cheese Diet Ice Confectionery Fish Milk Meat Starch/cereals	Feed
Xaa-Pro-dipeptidyl-aminopeptidase	*Lactococcus lactis*	*none*	Cheese Diet Egg Fish Meat Milk Spic	

Xylanase	*Aspergillus foetidus*	*none*	Bakery Starch/cereals	Feed
	Aspergillus niger	*Aspergillus sp.*	Bakery Beverages	Piglet. Pig rearing. Laying hens. Chicken /turkey rearing.
		none	Bakery Beverages Fruit	Feed
	Aspergillus niger var. awamori	*Aspergillus sp.*	Bakery	Feed
		none	Bakery	Feed
	Aspergillus oryzae	*Aspergillus sp.*	Starch/cereals	
		Thermomyces sp.	Bakery	Pig rearing. Laying hens. Chicken /turkey rearing.
	Bacillus amyloliquefaciens or subtilis	*Bacillus sp.*	Bakery Beverages Starch/cereals	Feed
		none	Bakery Beverages Starch/cereals	
	Bacillus licheniformis	*Bacillus sp.*	Starch/cereals	
	Humicola insolens	*none*		Piglet. Pig rearing. Chicken rearing.
	Trichoderma reesei or longibrachiatum	*Actinomadura sp.*		Piglet. Laying hens. Chicken /turkey rearing.
		Trichoderma sp.		Feed
	Disporotrichum dimorphosporum	*none*	Beverages	
	Penicillium funiculosum	*none*	Beverages Starch/cereals	Feed
		Trichoderma sp.	Beverages Starch/cereals	
		none	Bakery Beverages Starch/cereals	
	Trichoderma viride	*none*	Bake Starch/cereals	

*** Key to food categories:** Bakery = Baked goods
Beverages = soft drinks, beer, wine
Choc = Cocoa, chocolate, coffee, tea
Diet = Dietary food
Fats = Fats and oils
Fruit = Fruit and vegetables
Ice = Edible ice
Soup = Soups and broths
Spice = Spices and flavours
Sugar = Sugar and honey

Source: Modified from AMFEP (Association of Manufacturers and Formulators of Enzyme Products); original at http://www.amfep.org/main.html

Authors

Graham Brookes is an independent agricultural economist with 20 years experience of undertaking economic and market analysis of agricultural, food and feed sectors both globally and in the EU. He has considerable experience and knowledge of both the food and feed supply chains and is a specialist in the assessment of the impact of new technology on agricultural production systems and markets. He has undertaken numerous studies on the impact of GM technology both for the public and private sector.

Neville Craddock is an independent consultant with over 40 years experience in the food and food-related industry. He has a comprehensive understanding of food ingredients and additives, and their application in a wide range of foods. Neville was directly involved in the technical and political issues facing the food industry during its development and application of GM policy.

Professor Bärbel Kniel is a qualified food chemist with a long experience in R&D and Quality Management in the food industry. She has been closely involved, from the outset, in the GMO issue and corresponding technical, legal and marketing aspects and is now Managing Director of an independent consultancy, specialising in advising the European food and feed chain, with a strong focus on GMOs.

Note from the Authors

This independent report was Commissioned by Agricultural Biotechnology Europe at the request of varied players in the European food and feed supply chain who wished to have further information on the feasibility of maintaining current policies to exclude GM.