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Monica Natalia Haro

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ABSTRACT

Genetic modification technology has been suggested as a way to address challenges in aquaculture and other industries. For instance, the demand for fishmeal and fish oil in aquaculture industry is expected to increase rapidly, potentially resulting in increased prices. Salmon feed represents the majority expense (approximately 60-70%) of the total production costs. Genetically modified plants may be one option to replace the use of marine feed ingredients and at the same time reduce the expenses. By GMO technology it may also be possible to develop genetically modified fish, also called transgenic fish, to enhance desired characteristics such as increased growth, resistance to disease and cold tolerance.

The first objective of this thesis is to identify UMB students' knowledge, attitudes and degree of support towards genetic modification (GM) and the use of GMOs in aquaculture. The second is to explore whether the use of GM plants as ingredients in farmed salmon feed are acceptable as alternative feed resources, and if it is considered important among respondents to label the salmon as a GMO if the salmon has been fed with GM plant feed. Finding whether GM, Marker-assisted selection (MAS) and traditional selection are considered as acceptable methods to improve growth and/or disease resistance of farmed salmon is the third objective. A questionnaire was designed to gather response regarding these matters.

Through the questionnaire it was found that students seem familiar with GM and GMOs, knowing the definitions, method and purpose of the technology. Concerns expressed regarding the safety of using GMOs were particularly related to environmental impacts, but there were also concerns for human health, animal welfare and with regard to ethical aspects. In order to reduce the risk of GM applications, the majority of the students suggested doing more research on risk related aspects with GMOs, seeking expert advice, making the production of GMO and information about the technology more transparent as well as improving communication between scientists and the public.

When considering ethical aspects on GM technology, it was found that the use of GMOs are considered as "tampering" with nature among the majority (22%) of the respondents, but only to a small extent was this opinion based in belief of religion. Generally, students

are slightly positive to the use of GM technology for production of food, animal feed and non-feed, but more positive to the use of GM technology for saving human lives (e.g. medicine and vaccine production) and in production of vaccines to prevent disease.

Regarding GM technology, more studies on the long term effects and more transparency about research, was emphasized among the respondents. On the other hand, media was not believed to give an objective presentation about GMO.
There was some support to production of GM food when the purpose is to enhance nutrition value, but there were less support in the case of enhancing appearance (e.g. better color or shape), taste, price or shelf life. Freshness and sensoric quality was considered most important when buying salmon, while price, nutritional content and convenience in preparing/cooking were also considered important. Students have low interest in organic or long shelf life salmon. Students seem to be positive to buy transgenic salmon if it is more environmental friendly but have low interest to buy if it is more nutritious or disease resistant. Almost 1/3 of the students are willing to buy transgenic salmon if it is 20% cheaper, but any further reduction in price had only minor effect.

Nearly half (47%) of the respondents were willing to buy transgenic salmon if relevant authorities (e.g. Norwegian Food Safety Authority (Mattilsynet)) have approved it as safe. Perhaps UMB students have less trust in Norwegian Food Safety Authority than Norwegians in general, or less trust in the authorities with regard to this specific sector. Most students agreed that GM labeling is needed for GM food and transgenic salmon and that this is more important than labeling of salmon vaccinated with GM or DNA vaccines. The use of GM plants in feed for salmon has little support and most students requested a labeling of salmon fed with GM plant feed.

Students have highest support (50%) for traditional selective breeding to improve growth and/or disease resistance of farmed salmon. MAS and MAS combined with traditional selective breeding also got high level of support (34% and 39%, respectively), in contrast to the use of transgenic salmon (20%).

Key words: *GMOs, GMO technology, genetic modification, survey, transgenic salmon, GM feed, ethics, labeling of GMO products, marker-assisted selection (MAS)*

SAMMENDRAG

Genmodifisering er en teknologi som kan møte dagens utfordringer innen akvakultur og annen industri. Eksempelvis er behovet for fiskemel og fiskeolje innen fiskeoppdrettsindustrien ventet å øke raskt, noe som kan medføre stigende priser. Laksefôr representerer i dag innen akvakultur næringen i Norge over halvparten (ca. 60-70%) av de totale produksjonskostnadene. Genmodifiserte (GM) planter kan være en mulighet til å erstatte bruken av marine fôringredienser i tillegg til å redusere kostnadene. Ved hjelp av genmodifisering er det også mulig å utvikle GM fisk, også kalt transgen fisk, med forbedrede egenskaper som økt tilvekst, sykdomsresistens og toleranse for lave temperaturer.

Målsettingen med denne oppgaven er for det første å studere kunnskap, holdninger og støtte til genmodifisering og bruken av GMO i akvakultur blant studenter ved Universitetet for Miljø- og Biovitenskap (UMB). Videre å finne ut om bruken av GM planter er aktuelt som en alternativ fôr-ingrediens, og om det i så fall innebærer at laksen som har spist GM planter må merkes som GMO. Den tredje målsettingen er å finne ut om genmodifisering, markørassistert seleksjon (MAS) og tradisjonell seleksjon er vurdert som akseptable metoder for å forbedre vekst og/eller sykdomsmotstand hos oppdrettslaks. En spørreundersøkelse ble gjennomført for å samle inn data om disse temaene.

Via spørreundersøkelsen ble det funnet at studentene ser ut til å være godt kjent med genmodifisering og GMO, siden de kjenner definisjonene, metodene og hensikten med denne teknologien. Det ble uttrykt bekymringer rundt sikkerhet ved bruk av GMO, spesielt relatert til effekter på miljøet, samt for helse effekter hos mennesker, dyrevelferd og etiske aspekter. For å redusere risiko ved bruk av GM, foreslo flertallet av studentene å gjennomføre mer risiko relatert forskning på GMO, søke ekspert råd, gjøre informasjon om produksjon av GM og om teknologien mer åpen og tilgjengelig, samt forbedre kommunikasjonen mellom forskere og publikum.

Når de etiske sider ved genmodifisering ble vurdert, ble bruken av GMO av flertallet (22%) vurdert som "kludring" med naturen, men dette blir bare i liten grad sett i sammenheng med tro eller religion. Generelt ble det funnet at studentene var litt positive til bruk av GM når hensikten er å produsere mat, dyrefôr, andre produkter som tekstiler og kosmetikk,

men mer positive til bruk av GM når målet er å redde menneskeliv (for eksempel medisin og vaksineproduksjon), samt produksjon av vaksiner for å hindre sykdom.

Blant respondentene ble det funnet at når det gjelder GM er det behov for flere studier av langtidseffekter og nødvendig med mer åpenhet rundt forskningen. På den andre siden ble det svart at de ikke trodde at media gir en objektiv fremstilling av GMO.

Det gis noe støtte til produksjon av GM mat for å øke næringsverdi, mens det ble gitt mindre grad av støtte når hensikten er å forbedre utseende (for eksempel bedre farge eller form), smak, pris eller holdbarhet. Ferskhet og sensorisk kvalitet ble vurdert som de viktigste egenskapene ved kjøp av laks, men også pris, næringsverdi og lettvint tilberedning er viktig. Studentene viser liten interesse for økologisk produsert laks eller laks med lang holdbarhet. Studentene ser ut til å være positive til å kjøpe transgen laks hvis den er mer miljøvennlig, men har liten interesse for å kjøpe laks som har bedre næringsverdi eller er mer sykdomsresistent. Nesten en tredjedel av studentene var villig til å kjøpe transgen laks hvis den er 20% rimeligere, mens det ble funnet at en ytterligere prisreduksjon har liten effekt utover dette.

Nesten halvparten (47%) av de spurte var villig til å kjøpe transgen laks dersom relevante myndigheter (f.eks. Mattilsynet) godkjente det som trygt. Det er mulig at UMB-studenter har mindre tillit til Mattilsynet enn nordmenn generelt, eller mindre tillit til myndighetene når det gjelder akkurat denne sektoren. De fleste studentene var enig i at merking er nødvendig, og viktigere for GM mat og for transgen laks enn for laks vaksinert med GM eller DNA vaksiner. Det var liten støtte til bruk av GM planter i fiskefôr, og studentene ønsker merking av laks fôret med GM planter.

Studentene gir mest støtte (50%) til tradisjonell avl (basert på seleksjon) for å forbedre vekst og/eller sykdomsresistens hos oppdrettslaks. MAS alene (34%) eller i kombinasjon med tradisjonell avl (39%) har også bred støtte, i motsetning til bruk av transgen laks (20%).

Nøkkelord: *GMOer, GMO-teknologi, genmodifisering, undersøkelse, transgen laks, GM fôr, etikk, merking av GMO-produkter, markørassistert seleksjon (MAS)*

Sustainability Aspects of Applying GMOs in Aquaculture

I. INTRODUCTION

Aquaculture is growing more rapidly than any other global food producing industry, with an average annual growth rate of 8.3% between 1970 and 2008 (Food and Agricultural Organisation 2010). As aquaculture industry expands, the demand for fishmeal and fish oil as fish feed ingredients are expected to increase accordingly. Marine resources will soon not be able to provide according to the demands due to overharvesting of wild fish, climate change and environmental issues. This is especially relevant for aquaculture species like salmon, which are dependent on marine resources.

Within salmon aquaculture does feed represent the largest expense of the total production costs. The price of fishmeal and fish oil has been increasing quite considerably due to their limited availability (Naylor et al. 2009). To overcome the need for marine resources in feed production, exploration of other feed resources and research on feed ingredients have been initiated (Naylor & Burke 2005; Tacon & Metian 2008). For example, meal and oils from plants such as soybean, maize and rapeseed are at present used together with fish based products in feed. Even though approximately 60% of salmon diets in Norway are from fish based products, around 35% of the diets used nowadays contain plant oils and proteins in addition to minerals, vitamins and pigment (Ellingsen et al. 2009). Other plant resources used in fish feed are rapeseed, corn gluten, wheat gluten, barley, pea and lupin meals and oil from palm, soybean, maize, rapeseed, coconut, sunflower, linseed and olive (Tacon et al. 2006). There are some promising options for alternative farmed salmon feed resources such as species from lower trophic levels (e.g. Antarctic and North Atlantic krill, zooplankton, mesopelagic fish and some species of squid) (Waagbø et al. 2001), fishery by-products/catch (Huntington 2004; Tacon et al. 2006), land animal by-products (e.g. bone, meat, skin and feathers) (Turchini et al. 2009), plants (Gatlin et al. 2007; Tacon et al. 2006), genetically modified (GM) plants (e.g. GM soybean and maize) (Flachowsky et al. 2005), products from microorganisms (Miller et al. 2008; Naylor et al. 2009; Tacon et al. 2006), GM microorganisms (Waagbø et al. 2001) and nutritionally enhanced GM plants (Gatlin et al. 2007). Krill (a shrimp-like marine crustaceans) is at present utilized in aquafeeds (artificially compounded feeds for farmed finfish and crustaceans) as a high quality source of omega-3 polyunsaturated fatty acids PUFA), vitamins and minerals, essential amino acids, carotenoid pigments, nucleotides and organic acids (Suontama et al. 2007a; Tacon et al. 2006). There are some concerns related to using krill in feed, since it represents an important trophic level in the bottom of the food web and therefore harvesting may reduce food resources for predators and thereby have an adverse impact on marine ecosystems. Krill is also vulnerable to environmental changes and climate change (Tacon et al. 2006). In the study by Gillund and Myhr (2010), it was also found that there was insufficient knowledge about the effect of using lower trophic level organisms as feed ingredients since this would possibly not lead to a sustainable harvest.

I.1 Genetically modified organisms (GMOs)

According to the Norwegian Gene Technology Act is the definition of a genetically modified organism: a microorganism, plant or animal in which the genetic material has been altered by means of gene or cell technology (Gene Technology Act 1993). In the European Union regulation, genetically modified organisms (GMOs) are defined as organisms in which the genetic material (DNA) has been modified in a way that does not occur naturally by mating and/or natural recombination (Svåsand et al. 2007). Selected individual genes can be transferred from one organism into another, for example transferred between organisms that can traditionally breed (cisgenesis) as well as between non-related species (transgenesis).

First generation of GMOs was aimed to improve their agronomical properties. In the world, 73% of the commercially available and cultivated transgenic plants are tolerant of certain herbicides (mainly soy), 18% are resistant to certain devastating insects (corn, cotton and rape seed) and 8% have both properties (so called stacked events). There are also research initiatives into developing, GMOs modified according to other parameters as for example stress tolerance, nutritional enhancement etc. The development and the use of GMOs is a controversial topic globally.

An increasing portion of soybean, maize and rapeseed production on a world-wide basis is GM. Approximately 77% of soybean, 26% of maize and 21% of rapeseed cultivated globally are GM products (James 2010), and it is expected that this will continue to increase in the coming years (GMO-Compass 2010a). As time goes by it is more and more difficult to find GM-free products, especially soybean. According to the annual report on the worldwide commercial use of GM plants published by the agro-biotechnology agency (ISAAA, International Service for the Acquisition of Agri-Biotech Application), cultivation of GM plants increased globally since the first commercialization of biotech crops in 1996 (GMO-Compass 2010a). Hera and Popescu (2011) argues that GM plants cultivation has global impact in higher level of productivity and economic benefits. The up-to-date evaluation of cultivation and use of GMOs showed that there were strong reasons to promote the application of GMOs since it has not been registered any negative impact on the human and animal health, the biodiversity, the environment or by the gene transfer to conventional crops (Hera & Popescu 2011). There was a remarkable growth from 1996 until 2010, where the cultivation of GM plants exceeded for the first time, 1 billion hectares. It took ten years to reach the first 500 million hectares in 2005, but only five years to plant the second 500 million hectares to reach a total of 1 billion hectares in 2010 (James 2010). In 2010, there were 29 countries worldwide using biotech crops, amongst which 19 were developing countries and only 10 industrial countries (grew more than 1 million hectares on each country) (Figure 1). This number has been increased consistently from 6 in 1996, to 18 in 2003 25 in 2008 and 29 in 2010 (James 2010).

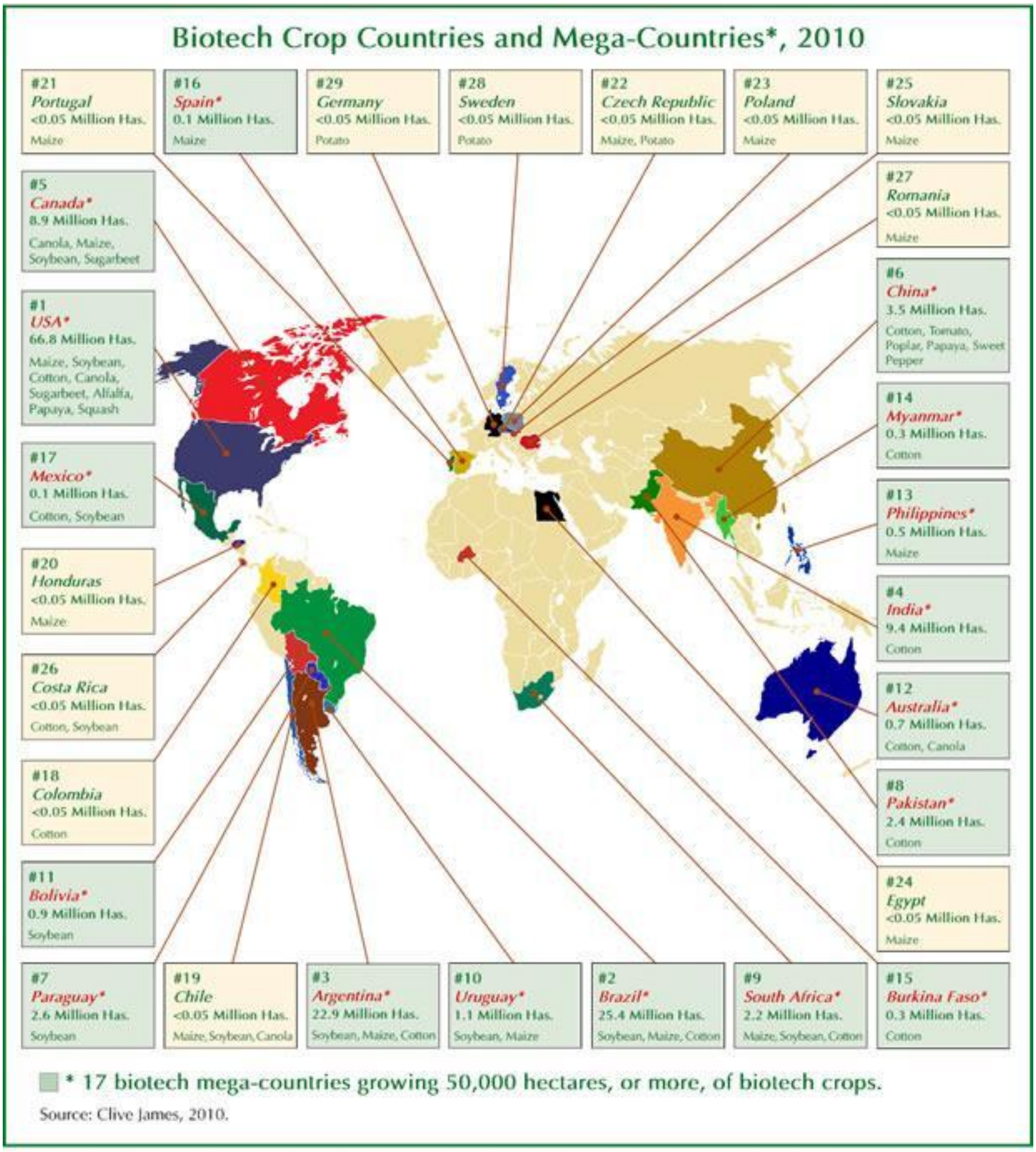

Figure 1: Global map of biotech crop countries and mega-countries in 2010 (James 2010).

By GM it can also be possible to provide new or alternative sources for salmon feed. For example, it may be possible to change the level of the antinutrients (e.g. phytic acid in soy) and nutrients (protein, fat and vitamins), starch structure, oil content and composition (omega-6 to omega-3) and other characteristics that will significantly improve plant's properties as an alternative salmon feed source (Gillund & Myhr 2010).

Microorganisms can be genetically modified to improve desired characteristics that are useful for salmon feed such as essential amino acids, omega-3 PUFA, vitamins, pigments, or enzymes for the breaking down of anti-nutrient factors (Waagbø et al. 2001). Bacteria, yeast and algae, can through a fermentation process using natural gas as an energy source, produce proteins and fatty acids for fish feed production (Miller et al. 2008; Naylor et al. 2009; Tacon et al. 2006). The availability of products from GM microorganisms is currently limited due to the difficulty to produce and the expensive price (Naylor et al. 2009).

GM and GMOs have been suggested as a way to address challenges as well as improving benefits of aquaculture (Melamed et al. 2002) and other industries. The rapid growth of aquaculture industry requires high quality feed sources, good fish health (disease resistant and improved tolerance to specific environmental conditions) and control of reproduction and sexual maturation. GM technology and the use of GMOs have been and will always remain controversial globally until the long-term impacts on health (animal and human) and concerns on ethical/animal welfare and environment issues are studied thoroughly and put into account. In the European consumer polls on attitudes to GMOs since 1996 to 2010, it was found a downward trend with fluctuations in the percentage of supporters (Gaskell et al. 2010). Consumers would be more supportive towards GMO products if they have benefits and are environmentally friendly (GMO-Compass 2009). Another trend is emerging from the latest survey by the Institute of Grocery Distribution in the UK. More than half of the British respondents (52%) considered GM technology as a solution against increasingly global food shortages, nearly half (47%) of respondents suggested GM plants as a solution to challenges in food production caused by climate change (i.e. increasingly extreme weather conditions and plant diseases) (GMO-Compass 2009).

In this thesis a survey was made and carried out as the basis of this master thesis at the Department of Animal and Aquacultural Sciences (IHA) at the Norwegian University of Life Sciences (UMB). The survey was conducted at the UMB because it is recognized that UMB is a leading international center of knowledge, with specialization areas in biology, environment, food, land use and natural resource management. These fields provide a broad range of disciplines that can be useful to perform a survey regarding knowledge, attitudes and degree of support on certain technology products. The main topic for the survey was to find attitudes among students to GMOs and especially to GMOs used in aquaculture. With the multidisciplinary sciences at the UMB, students are considered as relevant future stakeholders within agriculture and aquaculture research, development and policy. Hence, their attitudes and responses may influence in the future both positively and negatively to the general acceptance and development of GM in Norwegian agriculture and aquaculture.

DNA vaccines

Unexpected high mortality in aquaculture activities can occur at anytime. Vaccination is very important in aquaculture to control various threatening diseases (e.g. vibriosis, winter ulcer, furunculosis and bacterial kidney disease) and also considered to be a cost-effective method for protection against disease. In 1987, the administration of antibiotics in Norwegian fish farming reached its maximum of 49 tonnes. The administration to all Norwegian farmed fish in 2010 was 649 kg, which achieves a further reduction of about 664 kg, or 51% from 2009 (Directorate of Fisheries 2011). In order to reduce the administration of antibiotics, aquaculture industries have developed efficient vaccines to combat diseases. While vaccines offer the most efficient way to control infectious pathogens, current products have only been successful against some diseases, mainly of bacterial (Heppell & Davis 2000). Meanwhile, there has not been prophylactic treatment available for viral and parasitic diseases. The main challenges in using current vaccines in aquaculture are related to limited protection period and side effects. Infectious fish diseases have become more various and tolerant to the treatment (chemicals) without efficient vaccines available or because of very limited production of vaccines. It has been a major challenge to the development and profitability of aquaculture industries.

DNA vaccines have several advantages that may be very attractive for the aquaculture industry, in order to expand and fulfill the demand for fish and seafood products (Sommerset et al. 2005). DNA vaccines consist of a bacterial plasmid which contains a gene that code for an antigen against a specific pathogen. The vaccine is usually administered through intramuscular (i.m.) injection. If the injected plasmid DNA (pDNA) is taken up by an antigen presenting cell (APC), the specific antigen will be produced by the cells own apparatus (e.g. gene expression) and transported to the surface of the cell where it is recognized by immune cells, and finally stimulate the immune system.

DNA vaccines have been suggested as the most promising and potential fish vaccines (mainly for viral pathogens), and tested in several animal species as well as in humans. Some of the most promising results in aquaculture are the use of DNA vaccines against rhabdovirus diseases in fish (Cuesta et al. 2010; Lorenzen & LaPatra 2005). It was found that DNA vaccine induced rapid and long-lasting protection on farmed salmonids against economically important viruses such as infectious haematopoietic necrosis virus (IHNV) and viral haemorrhagic septicaemia virus (VHSV). In July 2005, the Canadian Food Inspection Agency has approved the IHNV DNA vaccine (Apex-IHN®) for commercialisation (Salonius et al. 2007). In the Norwegian aquaculture, it is suggested that better control of viral diseases can also be achieved through traditional combat principles. Improved strategies in avoiding and controlling of viral pathogens by breaking horizontal transmission of viral pathogens have proven to give good results both for the infectious salmon anaemia virus (ISAV) and for the pancreas disease virus (PDV) (Robertsen 2011).

It was found only two studies that describe research on DNA vaccines for infectious pancreatic necrosis virus (IPNV) (de las Heras et al. 2009; Mikalsen et al. 2004), and this may be due to lower protection in fish by DNA vaccines for non-rhabdovirus. Despite the potential advantages of DNA vaccines over conventional vaccines theoretically, there are some current problems of using DNA vaccines as shown in Table 1 (Lorenzen & LaPatra 2005). There are uncertainties on the potential ecological effects caused by the escape DNA vaccinated fish or the environmental distribution of DNA vaccines (Myhr & Dalmo 2005). If a labeling is required, for instance on salmon that has been vaccinated with DNA vaccine, it may affect the market price and the consumers' willingness to buy DNA vaccinated salmon.

Table 1 The advantages and disadvantages of DNA vaccines, modified from Lorenzen and LaPatra (2005). *particularly indicated in DNA vaccines for fish

Advantages	**Disadvantages**
▪ Generic and simple principle	▪ Challenge of delivery; require new approaches to vaccinate lots of small fish
▪ High level of safety-no risk of infectious disease	▪ Not efficient for all pathogens
▪ Combination of advantages of conventional vaccines	▪ Need more assessment on the long-term safety issues
▪ Alternative strategies if traditional vaccine fails	▪ Official distinction between GMOs and DNA-vaccinated animals' not always clear
▪ Activation of both humoral and cellular mechanisms *	▪ Public aversion in food products contain GMOs might influence market acceptance of veterinary DNA vaccines
▪ Multivalent vaccination possible by simply mixing of DNA vaccines *	▪ No regulation precedents yet available for DNA vaccines for husbandry animals
▪ Good effect when given at an early life stage *	▪ IPRs policy may affect the commercialization of veterinary DNA vaccines
▪ Protection induced shortly after vaccination and is long lasting *	
▪ Protection may work both in low and high temperatures *	
▪ Protection efficient across serotype variations *	
▪ Quick development of vaccines for new pathogen variants at low cost	
▪ High stability of purified product	
▪ Relatively low cost; easy production/quality assurance	

The regulation of DNA vaccines in Europe is still at an early- stage, therefore it requires directive research on the stability of the DNA construct towards the immunological impacts and the possibility of integration between the DNA construct and the recipient organism that may cause harmful effects (Gillund et al. 2008).

I.2 Marker-assisted selection (MAS)

Diseases make the second biggest concern in aquaculture industry after the issue of limiting fish feed resources. Besides the issues of ecological impacts from fish farms in general (as pollution), moreover the use of vaccines, and especially new vaccines based on genetic modification strategies, to combat diseases may cause unexpected effects. There is a likely pattern in the acceptance of new technologies where it is common to be skeptical towards the possible risks or even threat caused by the new technologies. We can take responsible acts or minimize the negative impacts to an acceptable level. Since the introduction of DNA marker technology in the 1980s, genetic markers linked to genes have been developed for application in genetic improvement. Quantitative trait loci (QTL) is localized regions of the genome containing genes affecting quantitative traits (Gjedrem & Baranski 2009) and with the help of genetic markers it is possible to control genetic development of these QTL and thus the characteristic which it controls (Moen et al. 2009). QTL may be considered as important to many traits of farmed salmon, showing continuous or quantitative variation. Knowledge of linkage between molecular genetic markers and QTL might facilitate the application of marker-assisted selection (MAS) for Atlantic salmon (Lie et al. 1997). MAS is a technology used to selectively breed future broodstock (a group of mature individual used for breeding purposes) based on their genotypes (Liu & Cordes 2004) for important traits (such as resistant to drought, diseases and other environmental stresses) without genetic modification. With MAS, it is possible to yield greater products such as genetic improvement, parentage control, and species identification (Rothschild & Ruvinsky 2007), while reducing the number of breeding steps to improve desired traits in organisms (Gjedrem & Baranski 2009). MAS is beneficial for genetic improvement on traits that are difficult or expensive to measure due to time limitation (e.g. feed efficiency, disease resistance and sexual maturation) or can only be measured as dead animal (e.g. fillet quality) (Gjedrem & Baranski 2009).

A current application of MAS in Norway is production of salmon fry with increased resistance to viral disease Infectious Pancreatic Necrosis (IPN) by Aqua Gen, the world's first selective breeding company in aquaculture (AquaGen 2010). The viral disease IPN is a highly contagious disease that causes high mortality in salmon, poor animal welfare and economic losses in salmon farming. Several advantages of QTL eggs are the fish will be protected against IPN from day one, the QTL gene marker could be applied directly on fish without performing challenge tests (sacrifice fish), increased cost-effectiveness and better animal welfare in aquaculture industry (AquaGen 2009). Aqua Gen has also a combination product from MAS technology in which high IPN-resistant eggs are combined with good growth and market quality characteristics (e.g. harvest result, fillet fat and color) (AquaGen 2009).

I.3 Objectives

The first objective of this study is to identify UMB students' knowledge, attitudes and degree of support towards genetic modification and the use of GMOs in aquaculture.

The second objective is to find more details on whether the use of GM plants for farmed salmon feed are acceptable as alternative feed resources and if there is a need for labeling the salmon as a GMO if the salmon has been fed with GM plant feed.

The third objective to the intention is to find whether MAS is considered as a more acceptable method compared to GM and traditional selection to improve growth and/or disease resistance of farmed salmon to get cheaper salmon or salmon that are healthy to eat. Since MAS is not a part of GMO, I was interested in comparing the level of support by using MAS with other methods such as genetic modification of the salmon (transgenic salmon), MAS combined with traditional selective breeding and traditional selective breeding without genetic engineering.

II. LITERATURE BACKGROUND

II.1 Previous studies on consumer attitudes to GMOs in Europe

A number of surveys have been conducted in Europe through EU-wide surveys on behalf of the European Commission, called Eurobarometer survey with varying results on GM products. From the period of 1996 until 2010, Eurobarometer survey has been surveying consumer behavior in Europe to track levels of support towards GMOs over time. There is some reluctance towards the introduction of GM food (Grunert et al. 2003), even though the Eurobarometer surveys (Gaskell et al. 2006) has revealed a progressive support towards GM food from 1999 to 2002. Surprisingly, it was found more skeptic consumers towards GM food from the Eurobarometer survey in 2005 (Gaskell et al. 2006).

According to the recent Eurobarometer survey conducted in February 2010, most Europeans were supportive towards the application of biotechnology, but more of them remained skeptical (from 27% support in 2005 to 23% support in 2010) regarding the application of genetic modification as GM foods (Gaskell et al. 2010). The European public was mostly concerned about the issue of safety, followed by the risks of GM food (Gaskell et al. 2010). By comparing the results from Eurobarometer in 2005 and 2010, it seems like there is no substantial difference in the public's perception of GM food. Results from the Eurobarometer across the period 1999 to 2010 showed that GMOs may still have chances in the European market, despite the downward trend in support for GM food.

In Norway, a multicriteria mapping (MCM) exercise was established to map the diverse perspective and to study the qualitative aspects of uncertainty in order to improve the information for decision making on future alternative feed resources for farmed salmon (Gillund & Myhr 2010). This study allowed a wide range of criteria to be identified (including issues around health and welfare, economical, environmental, knowledge and social aspects), and one of the finding was that the performance of the alternatives seems to be influenced by the values and interests of the respondents. As a result, the conclusions from the study were unclear in regard to the suitability of the feed resource alternatives. A study on consumers attitudes towards GMOs in Nordic countries conducted by Honkanen & Verplanken (2004) and Bech-Larsen & Grunert (2000), confirmed the negative attitudes of the Nordic populations towards GM food. Similar finding was found in some surveys for Polish consumers, resulted in having a significant distrust of genetic modification, especially in GM food (Janik-Janiec & Twardowski 2003).

II.2 Sustainability of salmon feed production

Sustainability can be closely defined as the ability to maintain functions continually after utilization (WCED 1987) in respect to environmental, socio-economic, biological and ethical considerations. Sustainability is a way to secure future needs by maintaining the diversity of resources in order to be able to cope with and adapt to future conditions. Norway, as the largest salmon producer in the world uses up to 60% of marine sources in the feed ingredients in order to maintain the quality of the salmon feed (Ellingsen et al. 2009). This percentage is considered very high in accordance to the sustainability of marine resources. It is predicted that, the marine resources will not be able to sustain the growing demand for fish meal and oil coming from aquaculture and other industries (primarily poultry, pig, pet feed and pharmacy). Salmon feed has largely been based on fishmeal and fish oil from wild marine fish (Ellingsen et al. 2009; Naylor et al. 2009). This is mainly because marine fish fulfill the nutritional requirements of carnivorous fish species and contain high levels of marine fatty acids (omega-3 PUFA) in the fish fillets with beneficial impacts on human health (Connor 2000).

The availability of natural raw material for carnivorous fish as salmon as their feed has to contain proteins, usually based on fish, a resource that has become limited and therefore caused an increase in feed price. Thus, the limitation and increasing prices of marine fish may be the main forces to find and develop alternative feed ingredients (Naylor & Burke 2005; Tacon & Metian 2008). A recent study on the perspectives on salmon feed (Gillund & Myhr 2010) showed a result that there were challenges to find a sustainable way for determining the suitable alternative feed resources. In this study it was found that participants were especially concerned about fish health and welfare, as well as economical, environmental, knowledge and social issues (Gillund & Myhr 2010). Whether the plant is genetically modified or not, using plants as part of salmon feed may have several challenges. Besides their low levels of protein and high starch, unfavorable amino acid and mineral profiles, high levels of fiber, the presence of anti-nutritional factors (ANFs such as lupin and phytic acid from soy) and/or antigens make it difficult to increase the amount of plants as ingredients in salmon feed resources as a carnivorous fish (Krogdahl et al. 2010; Medale & Kaushik 2009; Turchini et al. 2009). ANFs may be defined as secondary metabolites which are generated in natural feed stuff by the normal metabolism of species through different mechanisms which exert effects contrary to optimum nutrition. There is insufficient knowledge/studies about the effects on the replacement of fish meal and fish oil with plants as part of salmon diets (Hemre et al. 2009). According to Schubert (2008), it is necessary to do more safety assessment on GM plants with enhanced nutritional factors (such as vitamins, omega-3 fatty acids and amino acids) in order to understand the potential unintended impacts on health and the environment which are produced in GM plants. Partial replacement of marine resource by plant ingredients such as soybean, maize and rapeseed is being studied intensively in order to find alternative feed resources that are economically viable, nutritional satisfactory and sustainable (Medale & Kaushik 2009). The use of plant proteins and oils in fish feed, would improve the sustainability of production of farmed carnivorous fish, such as Atlantic salmon (Gatlin et al. 2007; Hardy 2010; Miller et al. 2008; Naylor et al. 2009; Tacon & Metian 2008; Turchini et al. 2009).

II.3 GM plants

GM plants are considered to be an alternative salmon feed source that is economical viable and sustainable aquaculture production (Connor 2000). GM plants are becoming more and more used worldwide. However, the introduction of GM plants raises new questions. The unknown impact of GM feed on the digestive microbial system and DNA fragments from GM feed that may be taken up by intestinal cells and then transferred through the circulatory system and distributed to other tissues and organs, remains a concern that needs research and long term assessment. A feeding trial on Atlantic salmon was conducted to study the fate of transgenic sequences in GM soybean as salmon feed (Sanden et al. 2004). In this study, Atlantic salmon were fed with three experimental diets for 6 weeks. The results from the feeding trials showed that in the fish gastrointestinal (GI) tract only smaller DNA fragment (120bp) could be amplified from the content of the stomach, pyloric region, mid intestine and distal intestine. Moreover, there were no transgenic or conventional soy DNA fragment detected in liver, muscle or brain tissues. The author argued that GM soy transgenic sequences may survive through the GI tract but they cannot be traced in fish tissues. Despite those results, the authors suggest that the study needs to be followed up, with feeding experiments over longer periods, investigation of more tissues, such as blood, spleen and gills, using not only PCR technology but also other method such as southern bloth electrophoresis. Moreover, Sanden (2004) also conducted a study focused on the fate and survival of ingested GM soy DNA fragments during feeding trials with Atlantic salmon post-smolt to investigate their survival through the fish gastrointestinal (GI) tract and whether the DNA could be traced in a variety of fish tissues. The result proposes that uptake and transport of soybean DNA fragments (GM and non-GM), from fish feed to peripheral tissues (liver, muscle and brain) in Atlantic salmon, did not occur. It was concluded that the fate of soybean DNA fragments was the same, whether it is a GM plant or a conventional plant feed source (Sanden 2004).

Sanden et al. (2006) conducted another feeding study to observe the growth performance and organ development in Atlantic salmon parr fed GM soybean and maize. The study indicated that the use of GM plants at a certain level in salmon feed had little or no adverse effect to health of first feeding Atlantic salmon parr and that they performed normally with regards to growth (Sanden et al. 2006). In line with this study, Bendiksen et al. (2011) suggested that replacement of fishmeals with plant protein sources to a large extend, resulted in no major detrimental effects on growth or feed utilization in farmed Atlantic salmon (*Salmo salar* L.). A large number of different bacteria colonize the intestines of fish. It is possible that these bacteria could be exposed to the recombinant DNA constructs in the digestive system of fish. With regard to fish fed GM feed, the potential of the horizontal gene transfer (HGT) between unrelated species to bacterial environment in the fish intestine has not yet been studied (Sissener et al. 2011). However, Sissener et al. (2011) argued that transgenic sequences might not taken up more frequently than regular plant DNA, neither the uptake caused any negative effects on fish.

Also studies have been carried out on salmon evaluating GM soy as part of feed ingredients, where the performance, health, organ function and stress response have been measured (Sissener 2009). One of these studies included a feeding trial that was conducted in 7 months salmon with GM soy (25%). As a result from this study, GM soy did not affect growth, body composition, hematology or weights of liver, spleen, head-kidney and proximal intestine, compared to non-GM soy. Moreover, no morphological differences were detected in any organs and no differences in performance during 7 months (salmon adapted well during the seawater transfer). It was concluded from this study that GM soy appeared to be as good as non-GM soy at a 25% inclusion level, which is higher than what is used at present in salmon feed (Sissener 2009).

II.4 Sustainability aspects in aquaculture

Aquaculture practice is dependent upon the environment, therefore it is extremely important to preserve the environment to continue the aquaculture activities on a sustainable basis. There are at present no universally agreement upon what sustainability implies for salmon farming or whether the aspects in aquaculture is sustainable. The major threats emerging from salmon aquaculture are escapes of farmed salmon (mating with wild population and perhaps outcompete native species); outbreak of diseases and the spread of parasites; pollution (e.g. fish excrement, feed waste, dead fish and chemicals) in the local environment; and increasing utilization of marine resources for feed production. Today, salmon louse (*Lepeophtheirus salmonis*), from the aquacultured salmon, is a threat to the wild salmon in Norway. There are regulations and treatments (i.e. delousing) to avoid the outbreak of salmon lice especially during smoltification (the period when wild salmon migrate from the river to the sea) between spring and early summer. According to the Directorate of Fisheries (2010), has salmon farming been banned since 2003 in several fjords and coastal areas in Norway to give protection for the most important salmon stocks against possible negative environmental impacts. However, there are some positive environmental impacts of aquaculture, that it may reduce overexploited wild fish stocks and that natural production around a fish farm may increase due to discards of organic material (Diana 2009). In 1994, the Holmenkollen guidelines for Sustainable Industrial Fish Farming were adopted to identify environmental hazards created by aquaculture, to define environmental objectives and to explain principles of conduct that may help meet environmental objectives (Svennevig et al. 1999). It provides guidelines for sustainable planning, application, preservation of genetic diversity and also research and education. The guidelines were reformulated in 1997 and adopted in 1998.

Scientific uncertainties in policy-relevant science

The intention by risk assessment is to provide information and advice for decision-making process of new technology. Scientists or experts in relevant fields will perform the analyzing of possible harms and/or risk that may occur from the new products or inventions. Policy makers investigate risks by evaluating the information and advice given by scientists, and compare the benefits with the risks. Felt and Wynne (2007) stated that this is an traditional approach which is based on an assumption that there is a difference between risk assessment and management, i.e. that risk assessment are factual and objective expert-led, while risk management is normative and value-based. The complexity of challenges faced by aquaculture industry currently requires new approaches to sustainable solutions (Frankic & Hershner 2003; Myhr & Dalmo 2005; Olesen et al. 2000; Olesen et al. 2010b). The complexity requires knowledge about uncertainties due to unpredictable nature of complex systems, limited scientific evidence to properly understand this complexity and the value-laden choices of scientific approaches (Gillund 2010).

Scientific uncertainties includes the "knowledge related (epistemological) uncertainties" which is described as a lack of scientific knowledge or a lack of tools and methodologies resulting in imprecise measurements/observations in experiments and the "variability related (ontological) uncertainties" which is arising due to inherent variability and diversity in the population or system under study (Walker et al. 2003). Uncertainties in scientific findings are usually expressed in quantitative statistical analysis, such as estimates of standard deviations, standard errors, confidence intervals or statistical tests for significance etc. However, these uncertainties are often considered as incomplete knowledge that can be reduced by further research. There are two types of uncertainties, risk and inexactness. Risk is a "magnitude of a possible hazard" multiplied by the "probability that a hazard will occur" (Stirling & Gee 2002). The risk of any hazardous outcome is dependent on the seriousness of the outcome and the likelihood for it to occur (Gillund 2010). Inexactness happens when all the hazardous outcomes caused by an activity are known, but there is a lack of sufficient knowledge to calculate the probabilities that each of the hazards will occur. Both risk and inexactness are quantitative types of uncertainty which may be characterized with statistics, reduced by continuous research and managed through the conventional approach of risk assessment (such as be able to identify the range of possible hazards and predict the probabilities of the occurrence) and risk management measures.

According to Walker et al. (2003), there are other dimensions of uncertainty which referred to as "qualitative dimensions", revealed by the multidimensional and unpredictable nature of ecosystems (indeterminacy, ambiguity and ignorance). Indeterminacy is a type of uncertainty that occurred by the complexity of various open-ended social and natural systems. There is a limitation to include all the relevant aspects and interaction in the investigation of complex systems (Gillund 2010). Ambiguity is occurred among experts and knowledge providers (i.e. scientists, policymaker, impacted parties and the public) due to contradictory information and/or the existence of divergent framing, assumptions and values. While ignorance is defined as inability to conceptualize, articulate and consider the outcomes and casual relationships behind the frameworks of understanding. It has been described as the things "we don't know that we don't know" and shows inability to ask the right questions, rather than a failure to provide the right answers.

People have diverse perceptions of uncertainties and risks, which may be influences by gender, education background and/or interests, profession and political preferences. Besides, people think of risks differently based on their level of knowledge about potential consequences, whether the risk is familiar and whether the risk exposure is undertaken voluntary versus being forced upon them (Slovic 1987). De Melo-Martin and Meghani (2008) argue that it should be known that defining what counts as a serious risk is a value-laden choice, as are choices of the time frame for investigating risks and what counts as evidence of risk (e.g. what level of statistical significance is used in the studies and what constitutes the baseline for comparison of harms). Consequently, although risk assessment is used for decision making, it is insufficient for addressing the social, ethical and cultural concerns relevant to the future of food production. A firm and determined decision to overcome uncertainties is greatly needed to manage new technologies such as the use of genetic modification in aquaculture, especially in regards to the issues raised on ethical/animal welfare and environment impact.

The precautionary principle

The precautionary principle is seen as a strategy to manage the complexity and uncertainty in science and decision making, with the purpose to avoid unintended hazardous consequences and yet have positive implications. The International Holmenkollen Guidelines for sustainable aquaculture have included the precautionary principle and the principles for environmental management inherent in the Rio Declaration of the UN Conference on Environment and Development and the Principles of Human Equity (Sundli 1999). The Rio Declaration takes into account the interdependence between biological, technological, socio-economic and ethical aspects (Sundli 1999). The application of the precautionary principle is relevant with regard to aquaculture activities when there is lack of information on risks to health and environment (FAO 1995). FAO (1995) established a global Code of Conduct for Responsible Fisheries (CCRF) to set up, maintain and develop an appropriate legal and administrative framework that facilitates the development of responsible aquaculture. Initiatives has also started by non-governmental organizations (NGOs) such as the Marine Stewardship Council which was established in 1996 by the World Wildlife Fund (WWF), a large environmental NGO, and Unilever, a consumer goods manufacturer and one of the world's largest fish processors (Aerni 2004). The purpose of this Council is to raise industrial awareness for sustainable fisheries, especially aquaculture, and to ensure the sustainability of world's fisheries. The implementation of precautionary principle must be based on indication of adverse effects, which are characterized by scientific uncertainty. According to Myhr (2010), a threshold of evidence of harm (e.g. where the magnitude of the harm is considered serious enough, and there is enough certainty about the probability for its occurrence, to implement the precautionary principle) has to be decided upon. In the case of GMOs, the precautionary principle has been included in the preamble of The Gene Technology Act (1993) in Norway and in the EU directive 2001/18/EC on deliberate release of GMOs into the environment.

Countries that have adopted a decision making process for approval of release of GMO for commercialization, emphasizes that this must primarily be evaluated as "case-by-case" and "step-by-step" approach. The "case-by-case" approach means that a scientific evaluation is mandatory for the approval of each case of GMO application. The "step-by-step" approach means that there is a progressive evaluation on the environmental impacts of GMOs release in order to decrease physical or biological containment (e.g. from greenhouse experiments, expanding to small scale and large field tests, eventually to market acceptance). Further, these approaches were intended to establish a learning practice and as a base of information for the authority and the companies (Myhr 2010).

II.5 Effects of GM on animal welfare, environment and ethics

Genetic modifications influence animal welfare in two ways, which are those involving intended and those involving unintended, genetic change (Sandøe & Christiansen 2008). More scientific research on impacts by GM and other new technologies are being carried out today to reduce the possible risks of unintended welfare problems. Besides the effects to the welfare of animals, GM technology may also have a negative effect on biodiversity. In animal breeding strategies, selection caused a loss of genetic diversity. The use of GM raises ethical dilemma, where on the one side, a human need, interest or preference, can imply a cost carried principally by the animals (Sandøe & Christiansen 2008).

The increasing production of aquaculture in Norway has been followed by a controversy among the stakeholders, involving fish farmers, consumers, non-governmental organizations (NGOs) and policy-makers, due to potential negative impacts on the environment and/or sustainability. Olesen and colleagues (2010b) has suggested new approaches to guide research for recognizing the ethical issues and for engaging stakeholders in order to improve sustainability of aquaculture. Aquaculture plays an important role in global food supply and therefore it is argued that it should aim for achieving sustainable production that is beneficial and economically viable in a long run with a minimal environmental impact.

II.6 Transgenic salmon

The first transgenic fish, a goldfish with a human growth hormone gene was developed in 1984 (Zhu et al. 1985), yet no transgenic food fish have been successfully commercialized in Europe. AquaBounty Technologies (a biotechnology company focused in improving productivity in commercial aquaculture) developed a GM salmon (known as AquAdvantage Atlantic salmon) by inserting genes from chinook salmon (growth hormone gene promoter) and eel-like fish/ocean pout (antifreeze protein gene promoter). Inserted genes can for example allow the modified salmon to grow twice as fast as non-transgenic salmon. Transgenic salmon is claimed to be sterile and has the same size at maturity as other farmed salmon (Aerni 2004). AquaAdvantage salmon is also reported to have improved feed efficiency (Aerni 2004; Du et al. 1992). The company proposed the AquAdvantage salmon to be approved by the American Food and Drug Administration (FDA) in 1999. The FDA is still considering whether the AquAdvantage salmon is as safe as conventional salmon. From a safety assessment carried out by the FDA, it was found that GM salmon material composition was indistinguishable from conventional salmon products (GMO-Compass 2010b). Moreover, the AquAdvantage applies for keeping the transgenic farmed salmon in containment and made sterile to avoid environmental risk such as breeding with wild salmon or other salmonid species if the transgenic salmon escape into open sea. It has been recognized that commercialization of transgenic fish will likely be dependent on the applicability and the effectiveness of the containment to reduce escapees from aquaculture activities (Devlin et al. 2006; Maclean & Penman 1990).

So even after more than eleven years, the Aquadvantage salmon (the first GM animal for food) is still in regulatory proceedings because it continues to raise concerns. Concerns were raised because there were insufficient data and information to make a conclusion on the allergenic potency of Aquadvantage salmon, the FDA has not been able to make a decision regarding the environmental assessment of the Aquadvantage salmon (Van Eenennaam & Muir 2011). If authorized in Norway, this may be the first transgenic animal approved in Norway for human consumption.

III. MATERIALS AND METHODS

Survey design and web-based survey

A web-based survey, the so-called "SurveyMonkey" was used as a platform to design a questionnaire. The web-based survey consisted of five different parts (i.e. general questions on GMOs, transgenic salmon, GM plants as part of salmon feed sources, MAS and demographic information) with 29 questions in total.

The survey was constructed to identify knowledge, attitudes and degree of support towards the use of GMOs in aquaculture. The survey was made available in English and Norwegian language, as the Norwegian University of Life Sciences (UMB) is an hosts of both Norwegian and international students. Bilingual survey was intended to give the students an option to take the survey in a language they were convenient with.

Each topic in the survey had question(s) that might be of interest to the respondents. The questionnaire was designed to make the questions with relevance to the thesis objectives and to provide valid data that could be useful for further studies or public knowledge. It was built to be short and concise with logic questions and good flow throughout the survey to make it interesting and to keep the attention of the respondents.

Two types of questionnaire with minor difference, with and without marker-assisted selection (MAS) question topic were made. The questionnaire with MAS topic was sent to students assumed to be more familiar and have relevant studies with MAS at the Department of Animal and Aquacultural Sciences (IHA), Department of Chemistry, Biotechnology and Food Science (IKBM) and Department of Plant and Environmental Sciences (IPM). While the questionnaire without MAS topic was sent to students who were assumed to be unfamiliar to MAS topic at the Department of Landscape Architecture and Spatial Planning (ILP), Department of International Environment and Development Studies (NORAGRIC), Department of Ecology and Natural Resource Management (INA) and Department of Economics and Resource Management (IØR).

A typing error was occurred in the third statement of the first survey question in the Norwegian version (see Table 2). Therefore we interpreted both statements as they were presented in the survey.

Table 2 Question 1 of the general questions in English and Norwegian version. Statement written in Italic is not a correct translation from the English version

English version	Norwegian version
1. How much do you agree or disagree on a scale from 1 to 6 with the following statements about genetic modification and GMOs?	1. Hvor enig eller uenig er du på en skala fra 1 til 6 i følgende utsagn om genmodifisering og genetisk modifiserte?
• Production of GMOs, such as transgenic animals, GM crops, GM microbes and GM vaccines, is carried out by deleting genes, by modifying genes or by adding gene constructs either from the same species or inter-species (e.g. insert a flounder gene into salmon).	• Produksjonen av GMOs som f.eks transgene transgene dyr, GM planter, genmodifisert mikrober og genmodifisert vaksine skjer ved å modifisere, sette inn eller overføre gener mellom arter (f.eks laks og flyndre) eller innen samme art.
• GM technology is useful in solving important challenges with feeding the world's increasing population and fighting disease.	• GM teknologi er nyttig for å løse viktige utfordringer som å produsere nok mat til en stadig voksende befolkning og bekjempe sykdommer.
• Genetic modification is genetic improvement of organisms by systematic breeding such as crossing and/or selection.	• *Genetisk forbedring av en organisme skjer ved systematisk avl som kryssing og/eller seleksjon av avlsdyr.*
• Development of GM technology is mainly driven by private companies and their desire for profit maximization.	• Utvikling av GM-teknologien er hovedsakelig drevet av private selskaper og deres ønske om stadig høyere lønnsomhet.

Trial test

Prior to launching the survey, it was tested among a small group of students chosen from close friends and schoolmates before it was submitted to the real respondents. The trial test was done to get a feedback of how the survey was presented in general and to get a picture of the difficulty of the level of the questions. After the trial test was done, revision was made and the survey was finally completed.

Incentives

To ensure a high respondent rate we offered an interesting incentive that could attract the students. Since students are considered as younger respondents, it was decided to offer a new 3D Sony camera released in April 2011 as a prize for a "lottery". The winner was randomly choosen among the survey participants. The lottery was optional and for those who would take part in the lottery it was required to write their e-mail address. It was emphasized that their response would still be handled confidentially. A computer sampled a random winner among the respondents taken part in the lottery and the winner got a new 3D Sony camera from us.

Survey population and distribution

The survey population consisted of all master and third year of bachelor students at the Norwegian University of Life Sciences (UMB). In total there were 1176 students eligible for the survey. We contacted all student advisors at the UMB to get an approval for distributing e-mail invitation to students at their responsible departments. After approval, student advisors distributed the e-mail invitation to all master and third year of bachelor students. One study program, Department of Mathematical Sciences and Technology (IMT), was not included due to communication challenges.

We distributed the survey through e-mail during 10 working days, started from 21st March 2011 until 30th March 2011. In the e-mail introduction, the purpose of the survey was described, and a link to the research project description was attached. The access to the information and the survey were made available by simply clicking on the links. It was estimated to normally take less than 20 minutes to fill out the survey though there was no time limitation. Respondents could exit and resume the survey at anytime if they would like to do so. A reminder through e-mail was sent out to increase the response rate a week after the invitation. Along with the reminder, an extra four days were offered to the students who had not yet participated in the survey after the deadline. A time and date for closing the survey set in the survey platform.

Data collection and analysis

All responses were collected and analyzed efficiently in the response collector and response summary on the "SurveyMonkey" platform. The survey was set to allow only one response per computer, respondents was allowed to go back to previous pages in the survey and update their responses until the survey was finalized or until they had submitted the survey. Also, they could go back after they had exited the survey before finishing it. After the survey was finished, the students could not re-enter the survey. There was a significant increase from 196 to 223 respondents in total, after sending a reminder through e-mail. The 215 respondents that completed all questions were used in the data analysis, in addition the 218 respondents that completed the general questions on GMO were still included in the analysis of the first eight questions.

The analysis of the results was carried out by using Microsoft Excel and chi-square (X^2) statistics run by SAS 9.1.3 software. For the analysis, data could be obtained either partly or by making a summary of all responses which could be set to different settings accordingly. The survey results were downloaded directly as excel files from the survey platform for data analysis. Excel was used to process data from the surveys and to combine the bilingual version to get a universal survey data to be used further in the analysis and in the statistical tests (chi-square-tests). In Excel format, we calculated the proportion of each response to the total response counted. By that, it will show the percentage of each response and make it possible to create figures and tables for comparisons. Additionally, we created a support rating system with scores from 1 to 6 based on the degree of agreement or support to each statement. Rating 1 represents low or no support, with increasing rate of support up to 6. Rating average was calculated as the sum of each frequency of response multiplied by the corresponding rating score.

Example for calculating the rating average:

How much do you agree or disagree on a scale from 1 to 6 with the following statement about GMOs?								
	Totally disagree 1	2	3	4	5	Totally agree 6	Total Response	Rating Average
Production of GMOs is safe.	6	4	11	22	39	106	188	5.14
	(3.2%)	(2.1%)	(5.9%)	(11.7%)	(20.7%)	(56.4%)	(100%)	

Rating average = (0.032x1)+(0.021x2)+(0.059x3)+(0.117x4)+(0.207x5)+(0.564x6) = 5.14

Statistical analysis

Chi-square test run by SAS 9.1.3 software was used to statistically test the hypothesis between observed data and expected data, and to identify whether the result occurred by chance, or they were due to other factors. First we tested the hypothesis whether the deviations were significant, then we interpreted the result to find if the *p-value* (where *p* is the probability that the deviation of the observed data from expected data is due to chance alone and that we reject the hypothesis although it is true i.e. Type I error) was statistically significant or not.

The significance level commonly used in research is $p = 0.05$. If $p > 0.05$, it means that that there is no significant difference at 5% level. Therefore, we accept the hypothesis of no difference (H_0) since the deviation is small enough that chance alone accounts for it. In contrary, if $p < 0.05$, it means that there is a significant difference at 5% level. Therefore, we reject the hypothesis of no difference (H_0) and conclude that some factor other than chance is contributing for the deviation.

Description of respondents

Based on the survey results from the demographic information of eligible respondents, the survey was responded by mostly women, 65%, while 35% men responded. In 2009 there were 57% female students at UMB, slightly increased from 2005 (56%). The age of the respondents were between 21 and 47 years, with most of the respondents (66.5%) were between 21 and 26 years old (1985-1990), and the least (6.8%) was between 32 and 47 years old (1964-1979).

Almost half of the respondents (45%) grew up in a small town/village. A smaller percentage of the students grew up in a big city (25%) and at a scattered place in the countryside (23%). Only 6% of the students grew up at the coast with fisheries and/or farms.

Most of the respondents had completed their bachelor degree (64%). Students who have completed their college and master degree represented a percentage of 17% and 13% respectively of the respondents. This showed that the students at the UMB that took part in this survey had higher educational background and were well-educated. Figure 2 shows that most students have education background and/or interest in Biology (49%). Many students also have education background and/or interest in environmental science/ecology (30%), nutrition (28%), genetics (26%), engineering/technology (24%) and animal health/disease (20%). There are 14% of the students that have education background and/or interest in social sciences and 13% in economics. The rest of the students have educational background and/or interest in plant sciences (4%), chemistry (3%) and others (2%). Only 1% of the students did not have any educational background and/or interest at all. From this information, most of the students have good knowledge and/or interest in the survey topics. Therefore their participation and responses can be considered as relevant for this study.

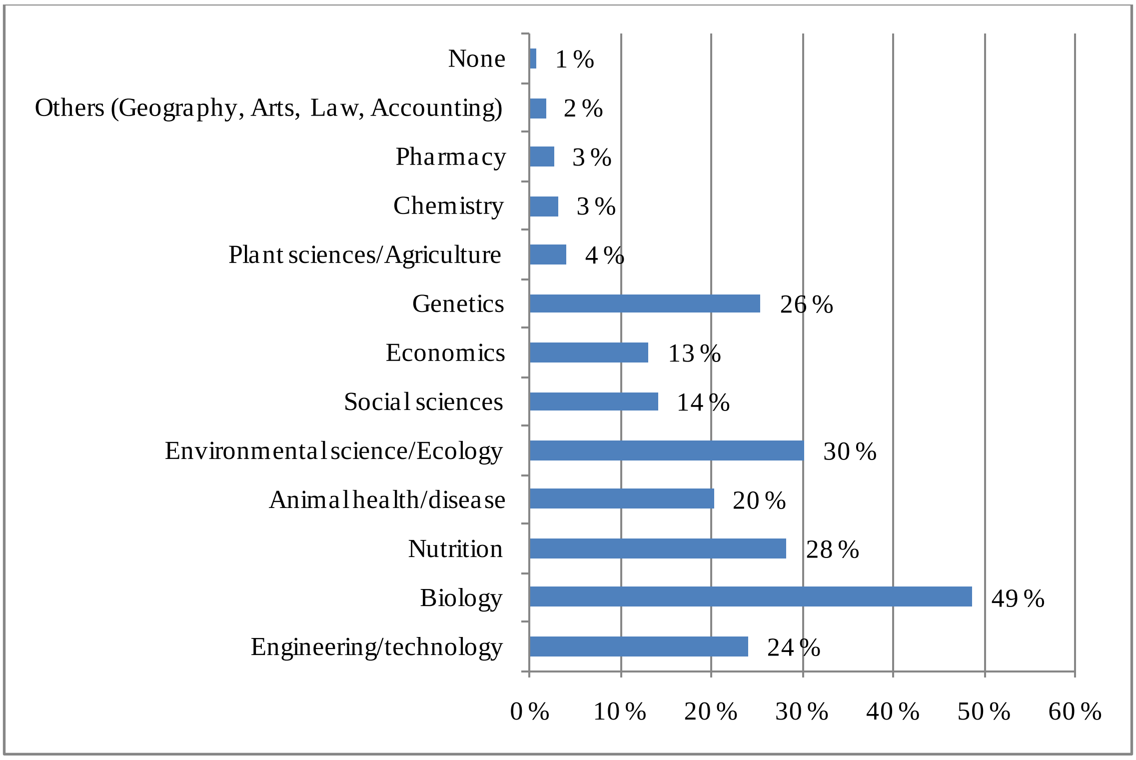

Figure 2: Field/discipline of education background and/or interest of respondents - Question 25. Bar length shows percentage of respondents.

The students that took part in the survey were grouped according to their current study program at the UMB as shown in Figure 3. The majority of the respondents (21%) were currently studying Chemistry, Biotechnology and Food science. The second biggest group (14%) of the respondents was studying Animal science. Many respondents were also studying Aquaculture (9%), International Environment and Development Studies (8%) and Biology, Molecular and Microbiology (8%). Some percentage of the respondents were studying Plant Science (7%), Environment and Natural Resources (6%), Ecology and Forest Sciences (6%), Nature-based Tourism and Renewable energy (4%), Economics, Business Administration and Resources Management (4%) and Feed manufacturing Technology (4%). The smallest groups of the respondents were studying Civil Engineering, Chemistry and Biotechnology (3%), Animal Breeding and Genetics (2%), Landscape Architecture and Spatial Planning (2%), Agroecology (2%) and Bioinformatics (1%).

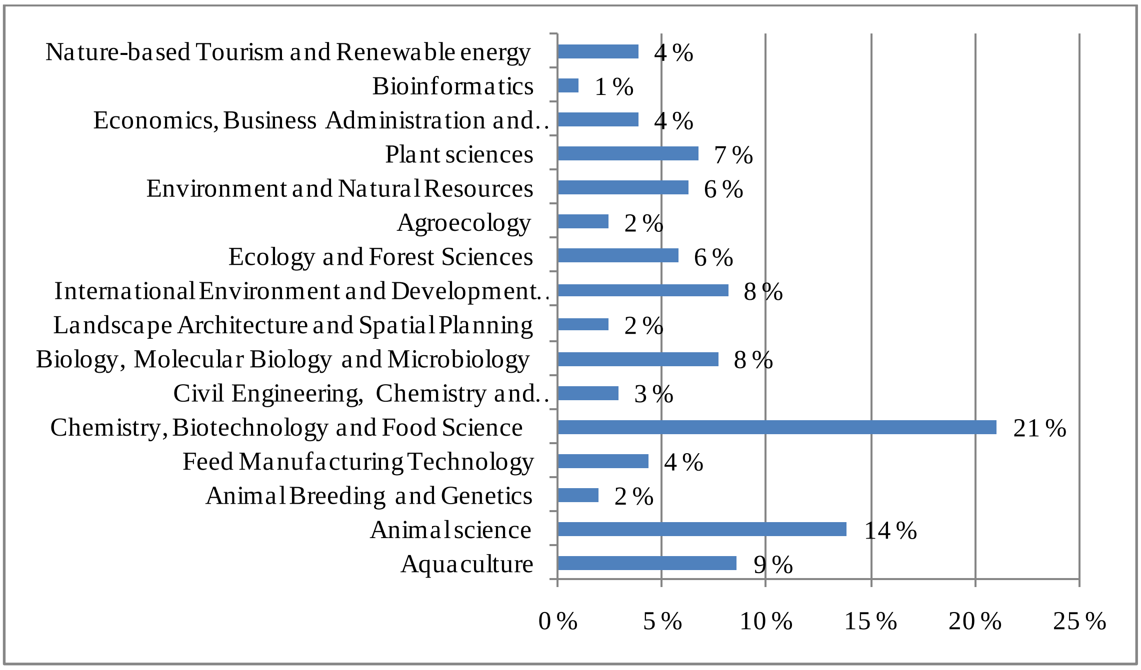

Figure 3: Respondents present study program – Question 26. Bar length shows percentage of respondents.

Most of the respondents described themselves to be an atheist or agnostic (59%) when they were asked about their belief in question 27. Only 9% described themselves as religious and 32% preferred not to answer this particular question.

Figure 4 presents the percentage of the students who would vote for a political party in a parliament election in Norway. Many of the students (18%) would vote for The Labour Party (Arbeiderpartiet). The second largest vote was for The Centre Party (Senterpartiet, SP), represented by 17% that was almost as high as the vote for The Labour Party (Arbeiderpartiet). The third largest party was the Socialist Left Party (SV) with 15%

of the votes. The Liberal Party (Venstre) got a little bit less than the vote for the Socialist Left Party (SV), which was 13% of the votes. While the Conservative Party (Høyre) and the Progress Party (Fremskrittspartiet, Frp) got only 9% and 6% of the votes, respectively. 18% of the students answered that if they could vote today they would prefer to not vote for any political party. In this group there were about 7% foreign students and about 11% Norwegian students. The reason for giving this answer may be that many of these students didn't want to vote for any political party or didn't know what to vote for since many were foreign students, hence were not familiar with political parties in Norway. The least vote was for the Red Party (Rødt), represented by only 1%, followed by The Christian Democratic Party (Kristelig Folkeparti, KrF), represented by 2%. Compared with the Norwegian political party election recently, we found some different results from this survey. For example, the Conservative Party (Høyre) and the Progress Party (Fremskrittspartiet, Frp) got a lot more votes than identified in this survey, in the Norwegian Parliament election autumn 2009, with position around the second or third winners of the elections. The results of the Norwegian Parliamentary (Storting) election from 1945 to 2005 are presented in Figure 5. However, the trend has not been a big difference than the recent election. The data obtained from the Statistics Norway shows that The Labour Party (Arbeiderpartiet, Ap) was still the largest party (35.4%) and the Progress Party (Frp) became the second largest party with 22.9% of the votes. Conservatives (Høyre) won the third largest party with 17.2% of the votes. Followed by the Center Party (Sp) and Socialist Left Party (SV) with 6.2% of the votes, Christian Democrats (KrF) with 5.5% of the votes, Liberal Party (V) with 3.9% and Red Party (Rødt) with 1.3% of the votes.

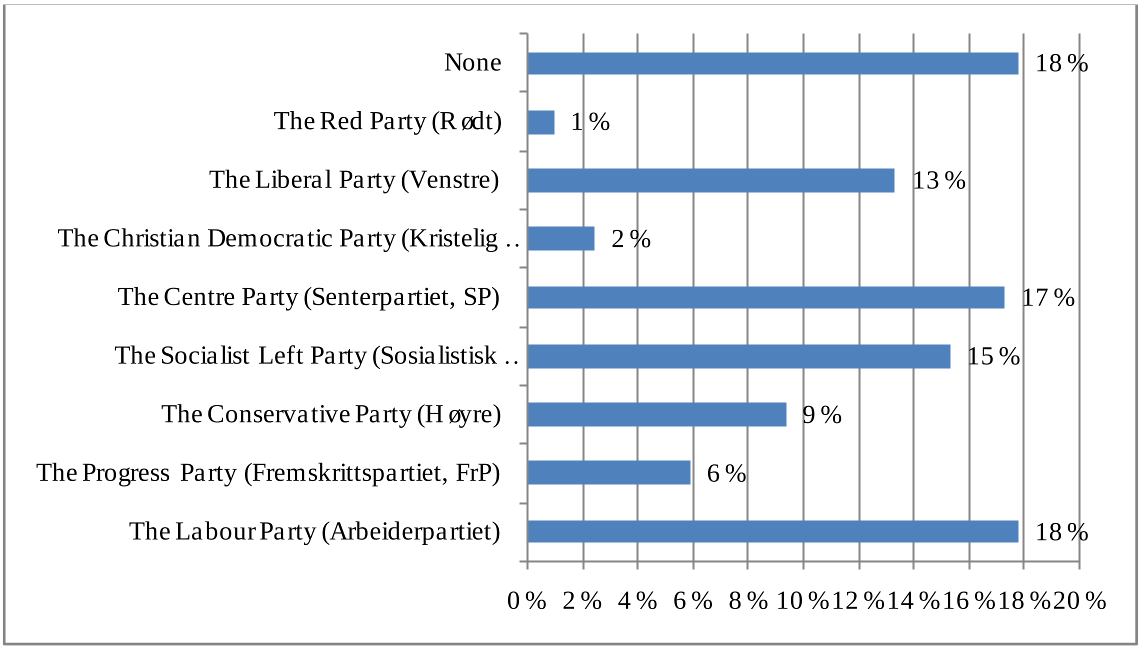

Figure 4: Political party respondents would vote for in a parliament election (*N*=203) – Question 28. Bar length shows percentage of respondents.

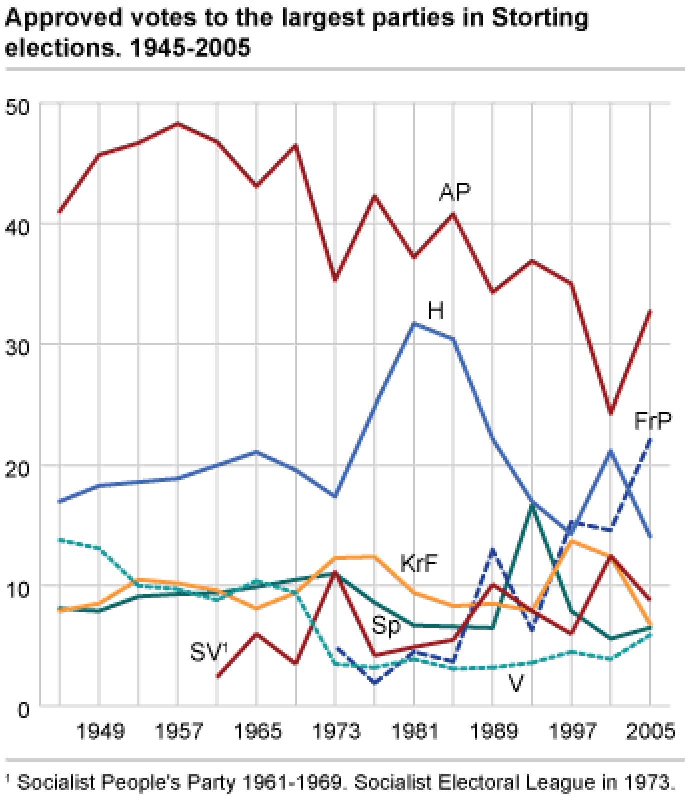

Figure 5: Approved votes to the largest parties in the Parliamentary (Storting) elections from 1945 to 2005 (source: Statistics Norway). The *x*-axis shows year of elections and the *y*-axis shows the total percentage of the vote.

On the last question of the survey of demographic information, the students were asked whether they were a member of one or more of organizations. 19% of the respondents were members of the Norwegian Trekking Association (DNT). The second largest member organization was the National Association for Hunting and Fishing e.g. Norwegian Association of Hunters and Anglers (Norges Jeger- og Fiskerforbund), represented by 12%, Environmental Organizations e.g. Bellona, Young Friends of the Earth Norway, Norwegian Society for the Conservation of Nature, The Green Warriors of Norway, was represented by 11% of the respondents. Only 5% of the students were members of the World Society for the Protection of Animals, WSPA e.g. Norwegian Animal Protection Alliance, Norwegian Animal Rights Organization; NOAH (Dyrevernorganisasjon f.eks Dyrevernsalliansen, Dyrebeskyttelsen). However, more than half of the students (63%) were not involved or member in any organization.

IV. RESULTS

IV.1 General questions

Question 1

Table 3 shows the responses of the first question about GM and GMOs. In the first statement, almost half of the students (49% or average score of 5.1) totally agreed that production of GMOs, such as transgenic animals, GM crops, GM microbes and GM vaccines, is carried out by deleting genes, by modifying genes or by adding gene constructs either from the same species or inter-species (as for instance the insert of a flounder gene into salmon). In statement 2, 24% of the students (average score of 4.1) agreed that GM technology is useful in solving important challenges with feeding the world's increasing population and fighting disease.

Unfortunately, a typing error was included in the Norwegian version (see Table 2). In Table 3 for the statement 3a, 22% of the students (average score of 3.7) were likely to agree that genetic modification is genetic improvement of organisms by systematic breeding such as crossing and/or selection. In the statement 3b, most students (44% or average score of 4.9) totally agreed that genetic improvement of an organism is done by systematic breeding such as crossing and/or selection ("Genetisk forbedring av en organisme skjer ved systematisk avl som kryssing og/eller seleksjon av avlsdyr").

On the other hand, only 17% of the students (average score of 4.0) totally agreed with the last statement that the development of GM technology was mainly driven by private companies and their desire for profit maximization.

Table 3 Degree of agreement with the statements about genetic modification and GMOs - Question 1. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average. Statement written in Italic is translated as 'Genetic improvement of organisms is made by systematic breeding such as crossing and/or selection'

How much do you agree or disagree on a scale from 1 to 6 with the following statements about genetic modification and GMOs?									
	Totally disagree 1	2	3	4	5	Totally agree 6	I don't know[a]	No. of responses	Rating Average
1. Production of GMOs, such as transgenic animals, GM crops, GM microbes and GM vaccines, is carried out by deleting genes, by modifying genes or by adding gene constructs either from the same species or inter-	3%	2%	5%	10%	18%	49%	13%	216	5.1

species (e.g. insert a flounder gene into salmon).									
2. GM technology is useful in solving important challenges with feeding the world's increasing population and fighting disease.	6%	13%	15%	19%	23%	24%	0%	216	4.1
3a. Genetic modification is genetic improvement of organisms by systematic breeding such as crossing and/or selection.	15%	12%	12%	22%	15%	20%	5%	41	3.7
3b. *Genetisk forbedring av en organisme skjer ved systematisk avl som kryssing og/eller seleksjon av avlsdyr.*	4%	3%	7%	16%	23%	44%	4%	177	4.9
4. Development of GM technology is mainly driven by private companies and their desire for profit maximization.	3%	14%	15%	16%	16%	17%	19%	216	4.0

Question 2

On the second question of the survey, most students agreed (average score of 5.0) on the statement that scientists want to make an improvement that can contribute towards effective problem solving e.g. feeding an increasing world population, fighting disease and enhancing sustainable production (Table 4).

They agreed to the least extend on the statement that researchers' motives are based on curiosity and a desire to improve our understanding of biotechnological methods (3.8 rate). However, some students believed in the statement that scientists might get caught up in a working situation with a pressure towards high and short term profit, and thereby get more or less forced to do research on GMOs. Table 4 indicates that the average score of 4.3 for this answer were slightly higher than the other statement on researchers' motives to improve our understanding of biotechnological methods (average score of 3.8).

Table 4 Degree of agreement with the statements about the safety of using GMO - Question 2. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

How much do you agree or disagree on a scale from 1 to 6 with the following statements about researchers motivation or condition to do research on GMOs:									
	Totally disagree 1	2	3	4	5	Totally agree 6	I don't know [a]	No. of responses	Rating Average
1. Scientists want to make an improvement that can contribute towards effective problem solving e.g. feeding an increasing world	1%	2%	5%	19%	29%	43%	1%	216	5.0

population, fighting disease and sustainable production.									
2. Scientists might get caught up in a working situation with a pressure towards higher short term profit, and get more or less forced to do research on GMOs.	4%	8%	13%	19%	24%	23%	9%	214	4.3
3. Researchers' motives are based on curiosity and a desire to improve our understanding of biotechnological methods.	4%	13%	23%	25%	19%	13%	4%	215	3.8

Question 3

In the last statement shown in Table 5, most students disagreed that the use of GMOs results in no negative environmental effects (average score of 2.1). Although a total of 39% agreed more or less that using GMO is ethically unacceptable, most students (a total of 58%) did not agree on this (average score of 3.1). There was a moderate disagreement on whether the statement about using GMOs in animal feed imply no risk to the animals' welfare (average score of 3.0) and in food imply no risk to human health (average score of 2.9). However, there was a high percentage of 'I don't know' answer for almost all statements concerning the safety use of GMO, 13% to 18% except the statement of using GMOs is not ethically acceptable (only 4%).

Table 5 Degree of agreement with the statements about researchers' motivation or condition to do research on GMOs - Question 3. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

Question 3. How much do you agree or disagree on a scale from 1 to 6 with the following statements about the safety of using GMO:	Totally disagree 1	2	3	4	5	Totally agree 6	I don't know[a]	No. of responses	Rating Average
1. Using GMOs in food implies in no risk to human health.	22%	19%	14%	11%	13%	7%	14%	216	2.9
2. Using GMOs in animal feed implies no risk to the animals' welfare.	20%	21%	14%	13%	13%	7%	13%	215	3.0
3. Using GMOs is not ethically acceptable.	18%	21%	19%	19%	13%	7%	4%	216	3.1
4. Use of GMOs results in no negative environmental effects.	35%	19%	17%	5%	3%	3%	18%	215	2.1

Question 4

Referring to Table 6, the majority of the students (67%) totally agreed that more research on GMOs is needed and that new knowledge about risks associated aspects must be taken into account in order to reduce the risk of GM applications. Responses on this question gave a quite high rating average of 5.5. More than half of the students (55%) believe that we need to seek expert advice to get more understanding about the potential risks to health and the environment, and also in this case there was a high rating average of 5.2.

Many students strongly agreed on the statements about the need to reduce the risk of GM applications by making the production technology more transparent (51% or average score of 5.2) as well as the need for improving communication between scientists and the public (52% or average score of 5.1). Only 7% disagreed more or less on this matter. Also, students were skeptical regarding the consequences of using GMOs represented by 19% (average score of 3.7), who doubted more or less that we can gain enough knowledge to reduce all possible risk of using GMOs since the consequences of using GMO is too complex.

Table 6 Degree of agreement on the statements about reducing the possible risks of GMOs application - Question 4. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

Question 4. How much do you agree or disagree with the following statements about reducing the possible risks of GMOs application: (check on a scale from 1 to 6)									
	Totally disagree 1	2	3	4	5	Totally agree 6	I don't know[a]	No. of responses	Rating Average
1. In order to reduce the risk of genetic modification applications we need to do more research on GMOs and take the new knowledge about risks into account.	1%	1%	3%	6%	22%	67%	0%	218	5.5
2. In order to reduce the risk of genetic modification applications we need to seek expert advice to get more understanding about the potential risks to health and the environment.	1%	3%	3%	14%	23%	55%	0%	218	5.2
3. In order to reduce the risk of genetic modification applications we need to make the production technology more transparent.	1%	2%	5%	13%	26%	51%	2%	218	5.2
4. In order to reduce the risk of genetic modification applications we need to improve communication between scientists and the public.	2%	2%	6%	11%	25%	52%	2%	218	5.1

5. The consequences of using GMOs is too complex. We can't gain enough knowledge to reduce all possible risk.	9%	17 %	19%	15%	16%	18%	8%	218	3.7

Question 5

In question 5 we asked the students about their level of agreement on statements regarding ethical issues on GM. Table 7 shows that 22% of the students agreed on the statement that using GM technology was "tampering" with nature (average score of 3.8). Students were to a less extent concerned about animal welfare (average score of 3.2), ethical issues (average score of 3.1) and on that GM technology was considered unnatural and ethically unacceptable method for medicine production (average score of 2.5).

In the first statement, the majority of the students (61%) totally disagreed that GM technology was against their belief/religion regarding ethical issues on GM, showed by average score of only 1.8. About 45% of the students (average score of 2.3) were mostly disagreeing on the statement about by using GM technology implies "playing God". While on statements about if GM technology was ethically unacceptable method in food and animal feed productions, an equal proportion of the students (21%) were mostly disagreeing on this matters (average score of 3.1 and 3.0, respectively).

Table 7 Degree of agreement on statements regarding ethical issues on GM – Question 5. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

Question 5. Regarding ethical issues on Genetically Modified (GM), how much do you agree or disagree on a scale from 1 to 6 with the following statements?									
	Totally disagree 1	2	3	4	5	Totally agree 6	I don't know [a]	No. of responses	Rating Average
1. GM technology is against my belief /religion.	61%	16%	8%	7%	2%	4%	2%	217	1.8
2. By using GM technology we are "playing God".	45%	18%	13%	12%	6%	5%	1%	217	2.3
3. GM technology is not acceptable in animal production due to animal welfare concerns.	18%	15%	21%	16%	12%	11%	7%	215	3.2
4. GM technology is not ethically acceptable in food production.	21%	18%	19%	18%	12%	9%	4%	217	3.1
5. GM technology is not an ethically acceptable method for producing animal feed.	21%	21%	19%	19%	9%	7%	5%	216	3.0

6. GM technology is not an ethically acceptable method for medicine production.	33%	21%	16%	13%	7%	5%	6%	215	2.5
7. Using GM technology is "tampering" with nature.	13%	10%	18%	21%	15%	22%	1%	214	3.8
8. GM technology is unnatural, and hence not acceptable.	33%	24%	17%	15%	6%	5%	0%	217	2.5

Question 6

In question 6 we asked the students about their level of agreement on statements about GM technology. Table 8 shows that most of the students (average score of 4.7) agreed that current research data tends to focus on the positive results of using GMOs while the potential long-term effects have not yet been sufficiently investigated. About the same proportion of students were agreeing on the statement that there is a lack of transparency to the public about research and information on GM technology (average score of 4.6). Many students agreed that media may give information that build fears about GMO without objective and scientific reasons (average score of 4.3).

Table 8 Degree of agreement on statements about GM technology – Question 6. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

Question 6. How much do you agree or disagree with the following statements about GM technology:									
	Totally disagree 1	2	3	4	5	Totally agree 6	I don't know[a]	No. of responses	Rating Average
1. Media provides information that build fears about GMOs without providing objective and scientific reasoning.	3%	5%	17%	22%	24%	22%	7%	217	4.3
2. Current research data tends to focus on the positive results of using GMOs while the long-term effects have not yet been sufficiently investigated.	0%	3%	10%	25%	21%	27%	14%	217	4.7
3. There is a lack of transparency to the public about research and information on GMO technology.	1%	5%	11%	21%	29%	28%	6%	217	4.6

Question 7

Table 9 indicates a very diverse opinions in question 7 on what purpose the students would support using GMOs for, except for the use of GMO technology for saving human lives (39% or average score of 4.9) and production of vaccines to prevent disease (33% or average score of 4.7). Use of GMOs for more sustainable meat production using farmed animals, production of animal feed and non-feed were equally supported with an average score of 3.8. The least support was offered the use of GMOs to produce cheaper food (average score of 3.2).

Table 9 Degree of agreement on statements about support on the use of GMOs – Question 7. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

Question 7. To what degree (on a scale from 1 to 6) can you support the use of GMOs for the following purposes?									
	Totally unacceptable 1	2	3	4	5	Fully acceptable 6	I don't know[a]	No. of responses	Rating Average
1. Production of cheaper food.	25%	15%	16%	18%	10%	15%	0%	217	3.2
2. Saving human lives (e.g. by producing medicines and vaccines).	3%	1%	9%	15%	32%	39%	1%	215	4.9
3. More sustainable meat production using farmed animals (e.g. more efficient production and less animal disease).	12%	10%	19%	24%	18%	17%	1%	216	3.8
4. Production of animal feed (e.g. from plants, algae and microorganisms).	12%	10%	14%	29%	18%	17%	1%	216	3.8
5. Production of non-feed (e.g. cotton and fabrics, cosmetics).	14%	11%	11%	24%	18%	19%	3%	216	3.8
6. Production of vaccines (GM and DNA vaccine) to prevent disease.	3%	4%	10%	18%	30%	33%	2%	217	4.7

Question 8

The students were asked in question 8 about their level of support on production of GM food assuming several conditions. Table 10 shows, that in general, the students had no support on production of GM food assuming the conditions of having longer shelf life (average score of 3.0), being cheaper (33% or average score of 2.9) and having better taste (27% or average score of 2.8). However, GM food being more nutritious, got a little support though the rate (average score of 3.4) was considered to be relatively low. Appearance such as better color or shape received lowest support (average score of 2.4) of all.

Table 10 Degree of support on production of GM food assuming the following conditions – Question 8. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

Question 8. To what degree (on a scale from 1 to 6) can you support production of GM food assuming the following conditions?									
	Non support 1	2	3	4	5	Full support 6	I don't know [a]	No. of responses	Rating Average
1. It is more nutritious.	18%	14%	15%	19%	13%	15%	6%	217	3.4
2. It looks more appealing (e.g. better color or shape).	45%	14%	15%	7%	9%	6%	4%	217	2.4
3. It has better taste.	27%	18%	19%	15%	8%	6%	7%	216	2.8
4. It is cheaper.	33%	14%	13%	12%	10%	13%	5%	215	2.9
5. It has longer shelf life (lasting ability).	27%	14%	17%	15%	13%	9%	5%	215	3.0

A chi-square test was conducted to test if study programs (question 26) were independent of responses to statement 4 in question 8. We found no significant difference (df = 30, Chi-square value = 32.16, $p > 0.05$).

Question 9

When the students were asked in question 9 about the frequency of eating salmon on average, the most frequent answer was two or three times a month (35%) followed by once a month or less (30%), as shown in Table 11. This indicated that most students eat salmon at least once a month. There were 8% of the students who never ate salmon.

Table 11 The frequency of eating salmon (N = 183) – Question 9

Question 9. On average, how often do you eat salmon?		
	Response Percent	No. of responses
More than once a week	13%	23
Once a week	14%	26
Two or three times a month	35%	64
Once a month or less	30%	54
Never	8%	15
I don't know	1%	1

Question 10

Table 12 shows the result of question 10 with regard to the importance of several criteria when buying salmon. Many students (28%) considered freshness as very important characteristic when buying salmon, and this criterion had a high average score of 4.4. Sensory quality (average score of 4.3) and price (average score of 4.1) are also considered important. Both nutritional content and convenience in preparing/cook (25%) seemed to be quite important among the students as well, represented by equally average score of 4.0.

Wild caught salmon (average score of 3.0) and salmon that has not been fed with GM feed (24% or average score of 3.1) were more or less important criteria when buying salmon. Organic salmon (36% or average score of 2.5) and long lasting salmon (27% or average score of 2.8) were not considered as important when buying salmon.

Table 12 The importance of several criteria when buying salmon – Question 10. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

Question 10. What do you consider as important when you buy salmon? (rate on a scale from 1 to 6 for each criteria)									
	Not important at all 1	2	3	4	5	Very important 6	I don't know [a]	No. of responses	Rating Average
1. Price	7%	7%	13%	27%	27%	16%	4%	211	4.1
2. Sensoric quality (visual appearance e.g. fillet color, taste, texture)	2%	6%	17%	22%	30%	19%	4%	211	4.3
3. Nutritional content	5%	10%	15%	25%	25%	14%	5%	213	4.0
4. Freshness	3%	7%	14%	19%	24%	28%	5%	210	4.4
5. The salmon has not been fed with GM feed.	24%	14%	13%	16%	13%	10%	11%	212	3.1
6. The salmon is wild caught (free range).	22%	19%	20%	14%	11%	9%	5%	212	3.0
7. The salmon is organic.	36%	17%	20%	8%	6%	8%	6%	213	2.5
8. The salmon has longer shelf life.	27%	18%	17%	17%	11%	5%	4%	212	2.8
9. The salmon is convenient to prepare/cook.	9%	7%	13%	23%	25%	15%	9%	200	4.0

IV.2 Transgenic salmon

Question 11

In Table 13 showing responses of question 11, it is showed that if transgenic salmon was more nutritious, 23% of the respondents were willing to buy and 36% were not willing to buy the product. However, many students (34%) responded "Maybe" they would buy it. The part of students not willing to buy transgenic salmon if it was more nutritious was almost as big as the group of students doubting to buy transgenic salmon.

Table 13 The percentage of willingness to buy transgenic salmon if it was more nutritious (*N* = 215) – Question 11

Question 11. Would you buy transgenic salmon if it is more nutritious?		
	Response Percent	No. of responses
Yes	23%	49
Maybe	34%	74
No	36%	78
I don't know	7%	14

Question 12

In Table 14 showing responses of question 12, nearly half of the respondents (43%) were not willing to buy transgenic salmon if it was more disease resistant. 21% of the students would buy transgenic salmon if it was more disease resistant, while 28% of the students responded "Maybe" they would buy it. Only 8% of the students responded that they didn't know.

Table 14 The percentage of willingness to buy transgenic salmon if it was more disease resistant (*N* = 215) – Question 12

Question 12. Would you buy transgenic salmon if it is more disease resistant?		
	Response Percent	No. of responses
Yes	21%	46
Maybe	28%	60
No	43%	92
I don't know	8%	17

Question 13

In Table 15 showing responses of question 13, 40% of the students would buy transgenic salmon and 39% would perhaps buy transgenic salmon if it were more environmentally friendly. 19% of the students would not buy it, while only 2% of the students did not know whether they would buy or not.

Table 15 The percentage of willingness to buy transgenic salmon if it was more environmentally friendly (N = 215) – Question 13

Question 13. Would you buy transgenic salmon if it is more environmentally friendly?		
	Response Percent	No. of responses
Yes	40%	86
Maybe	39%	83
No	19%	41
I don't know	2%	5

With the hypothesis that responses to question 13 is independent of responses to statement 4 in question 3, we found a significant difference ($p <$ 0.005) in a chi-square test (df = 15, Chi-square value = 39.68). Table 16 shows the percentage distribution from the chi-square test. Notice the tendency of increasing percentage of "Yes", with increasing agreement that the safety of using GMOs results in no negative environment effect.

Table 16 The percentage distribution of responses from question 3, statement 4 (agreement that the safety of using GMOs results in no negative environment effect) versus question 13 (willingness to buy transgenic salmon if it is more environmental friendly)

Question 3	**Question 13**				
	Yes	Maybe	No	I don't know	*N*
Totally disagree 1	28.00	40.00	30.67	1.33	75
2	44.44	38.89	16.67	0.00	36
3	45.95	51.35	2.70	0.00	37
4	70.00	10.00	10.00	10.00	10
5	66.67	0.00	16.67	16.67	6
Totally agree 6	80.00	20.00	0.00	0.00	5
N	69	65	32	3	169

We did not find a significant difference but a strong tendency (0.05 < *p* > 0.1) in a chi-square test (df = 3, Chi-square value = 7.71). This indicates that men were more positive than women to buy transgenic salmon if it was more environmental friendly.

Table 17 The percentage distribution of responses from question 21 (gender or respondents) versus question 13 (willingness to buy transgenic salmon if it is more environmental friendly)

Gender	**Question 13**				
	Yes	Maybe	No	I don't know	*N*
Men	52.70	31.08	13.51	2.70	74
Women	33.58	43.07	21.17	2.19	137
N	85	82	39	5	211

Question 14

The students were asked in question 14 whether they were willing to buy transgenic salmon if it was 20% cheaper and 31% of the students were willing to buy, while the rest (69%) still hesitate or will not buy at these conditions, as shown in Table 18.

Table 18 The percentage of willingness to buy transgenic salmon if the price is reduced by 20% (Question 14) and 30% (Question 15)

Willingness to buy transgenic salmon if it is cheaper:		
Response	**20% cheaper**	**30% cheaper**
Yes	31%	34%
Maybe	26%	25%
No	36%	33%
I don't know	7%	7%

With the hypothesis that responses to question 14 is independent of responses to statement 1 in question 7, we found a significant difference (*p* < 0.0001) in a chi-square test (df = 15, Chi-square value = 77.1547). Table 19 shows the percentage distribution of responses from the chi-square test. Notice the increasing and decreasing percentage of "Yes" and "No" respectively, with increasing support on the use of GMOs for production of cheaper food.

Table 19 The percentage distribution of responses from question 7, statement 1 (support on the use of GMOs for production of cheaper food) versus question 14 (willingness to buy transgenic salmon if it is 20% cheaper)

Question 7	**Question 14**				
	Yes	Maybe	No	I don't know	*N*
Totally unacceptable 1	5.66	16.98	69.81	7.55	32
2	10.71	28.57	57.14	3.57	19
3	22.58	35.48	32.26	9.68	37
4	45.95	35.14	10.81	8.11	53
5	63.16	21.05	10.53	5.26	31
Totally acceptable 6	59.38	25.00	6.25	9.38	28
N	15	53	71	61	200

Question 15

From the non-supportive and doubt responses (69%) in question 14, showed in Table 18, students were asked again in question 15 whether they were willing to buy transgenic salmon if it was 30% cheaper. Only 5% of these students changed their attitude to be willing to buy transgenic salmon if it was 30% cheaper, increasing the overall support from all respondents to about 34%. Still, about 33% of the students were not willing to buy transgenic salmon under these circumstances. This percentage is only 3% units less than if transgenic salmon was 20% cheaper. A chi-square test resulted in no significant difference ($p > 5\%$) between the answers from 'negative' and 'skeptical' students (responded "Maybe", "No" and "I don't know" if 20% cheaper) and the answers from the same students when given another option to pay 30% less.

Question 16

In question 16, the students were asked about their willingness to buy transgenic salmon if relevant Norwegian authorities (e.g. Norwegian Food Safety Authority) have approved it as safe. Table 20 shows that almost half of the respondents (47%) were willing to buy transgenic salmon if it was approved by authorities. Further another half gave "Maybe" and "No" answer, if relevant authorities (e.g. Norwegian Food Safety Authority) have approved it as safe.

Table 20 The percentage of willingness to buy transgenic salmon if relevant Norwegian authorities (e.g. Norwegian Food Safety Authority) have approved it as safe (*N* = 209) – Question 16

Question 16. Will you buy transgenic salmon if relevant Norwegian authorities (e.g. Mattilsynet) have approved it as safe?		
	Response Percent	No. of responses
Yes	47%	99
Maybe	26%	55
No	22%	47
I don't know	4%	8

Question 17

In question 17 in the survey, students were asked about the necessity on labeling of GMO products in Norway. Figure 6 shows that many students more or less agreed on the need for labeling of GMO products in Norway, mostly on GM food (represented by 84%), followed by transgenic salmon (69%) and salmon that have been vaccinated with GM vaccine (52%). Besides the responses from this question, we also received interesting comments on this particular matter both from the pro and contra on labeling of GMO products. Some of the students suggested that labeling is a must for all products containing GMO, while others suggested that labeling should disclose information on how GMO products particularly are produced, which traits have been modified and the benefits achieved. In addition to labeling, some suggested that a small label/sign on the products is enough, in order to not scare the consumers. About the same percentage, 7% of the students did not know if labeling on GMO products was necessary in Norway.

However there was a minor percentage, 7% of the students, yet reasonable suggesting that labeling of GMO products is not necessary at all. Some of their arguments were that as long as the product passes approval for consumption, the fact that it is GMO or has been fed GMO no longer matters, and that it is more important to provide certifications/labels for systems and companies that manage fish welfare and environmental concerns.

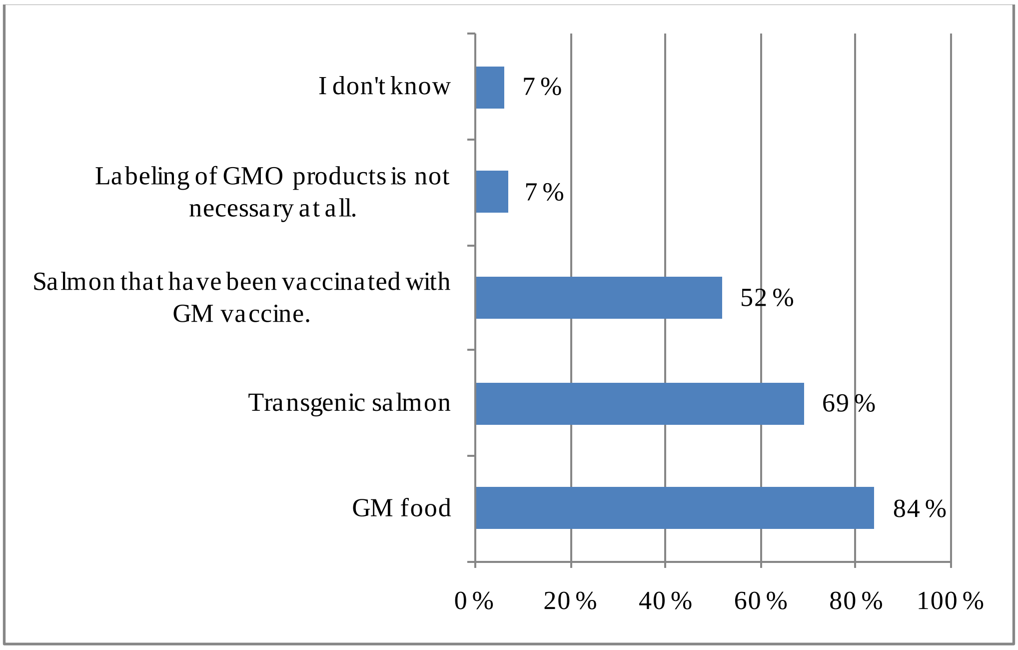

Figure 6: The necessity of labeling on GMO products in Norway – Question 17. Bar length shows percentage of respondents.

IV. 3 GM plants as part of salmon feed sources

Question 18

In Table 21, showing results from question 18, it can be seen some, but relatively low support for using GM plants as replacement for fish oil in salmon feed, represented by an average score of 3.72.

Table 21 Degree of support on using GM plants as salmon feed that may replace for example fish oil from fisheries – Question 18. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average.

Question 18. To what extent do you think that using GM plants as salmon feed is acceptable that may replace for example fish oil from the fisheries?									
	Totally unacceptable 1	2	3	4	5	Totally acceptable 6	I don't know [a]	Response Count	Rating Average
Response Percentage	11%	9%	17%	23%	12%	15%	13%	215	3.72

Question 19

Table 22 shows, in general, students requested a labeling of salmon as a GMO if the salmon has been fed with GM plant feed (41% of the respondents did totally agree with an average score of 4.55).

Table 22 Degree of agreement whether it is necessary to label the salmon as a GMO if the salmon has been fed with GM plant feed – Question 19. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

Question 19. How much do you agree or disagree on a scale from 1 to 6 that it is necessary to label the salmon as a GMO if the salmon has been fed with GM plant feed?									
	Totally disagree 1	2	3	4	5	Totally agree 6	I don't know [a]	No. of responses	Rating Average
Response Percentage	7%	6%	12%	16%	16%	41%	2%	215	4.55

IV.4 Marker-assisted selection (MAS)

Question 20

Table 23 presents the result from question 20, about acceptable methods to improve growth and/or disease resistance of farmed salmon to get cheaper salmon or salmon that are healthy to eat. This result revealed that the highest support was for traditional selective breeding without genetic modification (50% of the total answers and an average score of 5.0). There was a significant difference between the supportive group (82%) and the non-supportive group (only 14%). The second most acceptable method was MAS combined with traditional selective breeding, represented by 39% of the total answer or average score of 4.9. There was also a much bigger supportive group (79%, from rating 4-6) than the non-supportive group (12%, from rating 1-3) in this matter. MAS technology had equal support (34% of the total answer or average score of 4.8) as the previous method. The proportion of supportive group (77%) was also bigger than the non-supportive group (17%) in this matter. An exception was the method of GM salmon (transgenic salmon) that had the least support of all, represented by an average score of 3.3. Although in this matter transgenic salmon got the least support from all methods mentioned in the question, the proportion between supportive (43%) and non-supportive (48%) groups was quite equal.

Table 23 Acceptable methods to improve growth and/or disease resistance of farmed salmon to get cheaper salmon or salmon that are healthy to eat – Question 20. The table shows the percentage distribution of different responses, number of responses and a rating average, where the lowest value of 1 indicates totally disagreement and the highest value of 6 indicates totally agreement to the statement. [a] is excluded from rating average

Question 20. Which of the following methods do you find acceptable to improve growth and/or disease resistance of farmed salmon to get cheaper salmon or salmon that are more healthy to eat? (rate on a scale from 1 to 6)									
	Totally unacceptable 1	2	3	4	5	Fully acceptable 6	I don't know [a]	No. of responses	Rating Average
1. MAS	1%	4%	12%	17%	26%	34%	7%	164	4.8
2. Traditional selective breeding without genetic engineering.	2%	2%	10%	14%	18%	50%	3%	163	5.0
3. MAS combined with traditional selective breeding.	1%	2%	9%	15%	25%	39%	8%	165	4.9
4. Genetic modification of the salmon (transgenic salmon).	16%	17%	15%	20%	10%	13%	8%	165	3.3

V. DISCUSSION

The survey conducted for this thesis aimed to study the knowledge and current concerns attitudes on using GMOs in aquaculture among students at the UMB. By assessing the survey responses, we studied the possible aspects of GMO that may be accepted and useful to ensure sustainability in aquaculture. There were five topics in the survey, including general questions on GMOs, transgenic salmon, GM plants as part of salmon feed sources, marker-assisted selection (MAS) and demographic information. The chosen topics were designed to have a relevance to aquaculture studies and at the same time might be an interest to the respondents.

V.1 Genetic modification technology

The first general question was made to identify the level of knowledge among the students on genetic modification technology and GMOs. From the survey response of question 1, most of the students know what a GMO is. They chose the 'right' answer (agree or totally agree), while only a few percent disagreed (Table 3).

An error was found in the Norwegian translation of a statement (Table 2), and hence the evaluation of the answers had to take into account the different meanings of the English and Norwegian version. The result from the English version showed that 22% of the students agreed that genetic modification is genetic improvement of organisms by systematic breeding such as crossing and/or selection (see Table 3, statement 3a). In fact, genetic modification is not genetic improvement of organisms by systematic breeding such as crossing and/or selection. Genetic modification is a technology that is used for the development of GMOs, such as transgenic animals, GM crops, GM microbes and GM vaccines. This technology is carried out by deleting genes, by modifying genes or by adding gene constructs either from the same species or inter-species (as for example insert a flounder gene into salmon). Genetic improvement by crossing and/or selection is a method used to improve the characteristics of the next generation by breeding between species, breeds, populations, strains or inbred lines (Gjedrem & Baranski 2009).

From the Eurobarometer 1996 until 2005, it was found a difference between Europeans and the UMB students in their willingness to buy GM food. Almost half (49%) of Europeans were willing to buy GM food if they were more environmental friendly (51% if they contained less pesticide) but neither approval by the relevant authorities nor lower prices seemed to be good reasons to buy GM food (Gaskell et al. 2006; GMO-Compass 2009). From the survey we have conducted among students at the UMB, we found some results that are similar to findings from the Eurobarometer 2005. In both surveys, respondents were more willing to buy GM food if it was more environmentally friendly, but were less willing to buy GM food even though the price was cheaper. On the other hand, different from the result from Eurobarometer 2005, many of our survey respondents (36%) would not buy transgenic salmon if it was more nutritious (or considered to be healthier). From Eurobarometer 2006, around one third of the respondents were willing to buy GMOs if they contained less pesticide (environmental concern) or if they provide an additional price advantage (lower price coupled with consumer benefit - i.e. "spray-free" of GM fruits) than the conventional products (GMO-Compass 2007). These survey results imply that GMOs may become more accepted than was previously expected, if there is clear information of consumer benefit and environmentally friendly GM products.

The results in Table 4 shows that the students' opinion about researchers' motivation or condition to do research on GMOs is pro-active and has a practical purpose such as solving problems to feed the world, to fight diseases and create sustainable production. Many students thought it was possible that scientists might feel the pressure to gain a short term profit and get more or less forced to do research on GMOs. On the other hand, many students (average score of 3.83) doubted the researchers' motivation to study GMOs because they were curious and wanting to improve our understanding of biotechnological methods.

Table 5 shows that students concerns regarding the safety of using GMO are particularly about environmental impacts, but also for human health (22%), animals' welfare (21%) and ethical concerns. Before GMOs are commercialized in the market as food and/or animal feed, they have to pass through a regulatory safety assessment as required by the law in respective countries (i.e. Norway under the Gene Technology Act and EU nations under EU regulations). Up until now, in the EU, most of the GMOs that have been notified for regulatory approval and assessed for their safety as food and feed are derived from crops and microorganisms.

The large number of "I don't know" response (13-18%), for some of the questions, might represent the real situation, and not just ignorance among students. Perhaps students believe that the safety by use of GMOs is too complex, as almost half of the students (49%) more or less agreed to (statement 5 in question 4). We cannot know the immediate consequences from using GMOs. However, the survey did not include questions to identify the reasons behind the answer "I don't know".

There seemed to be some common understanding among the students about reducing the possible risks of GMOs application (Table 6). The majority of the students encourage the reduction of the risk of GM applications by doing more research on unwanted environmental and health effects by GMOs, seeking expert advice, making more transparency around production of GMOs and about the GM technology, and improving communication between scientists and the public. UMB students might be future scientists, and can perhaps be expected to be more positive to research than average population. However, there was some skepticism or realism among students regarding how much knowledge we can get from research to reduce all possible risk from using GMOs (see Table 6). As we mentioned, risk is a "magnitude of a possible hazard" multiplied by the "probability that a hazard will occur" (Stirling & Gee 2002). There may also be uncertain and complex consequences of using GMOs, which consequently makes the students raising question about the potential risks it may have to health and environment. Reducing uncertainties is the purpose of science to gain knowledge in order to improve the understanding of the obstacles (both "knowledge related" and "variability related" uncertainties). Scientists have limited capacity to fully identify the complexity and in suggesting scientific approaches to acknowledge uncertainties due to the unpredictable consequences of using GMOs.

Many respondents in this survey, and consumers in general, have been concerned about ecological and ethical matters of using genetic modification technology, particularly in aquaculture. Many people suggest that we should put limits on researchers' interference with nature. When asked about ethical issues on GM, most respondents in this survey pointed out that using GM technology is "tampering" with nature. The problem with "tampering" with nature may be reduced if we can properly predict the long-term consequences of using GM technology. Since this question could not be directly linked to belief or religious conviction, this may be related to the issue of complexity of ecosystems and the potential long term effects by GMOs. For example the possibility of escapees (e.g. transgenic fish and GM plants) and gene transfer (from GM food/ feed to bacteria in the intestines or the environment as well as pollen to wild relatives) from GM products may alter the genetic diversity of the relatives or wild populations. In fact, it has been proved that there was genetic interaction between escaped farmed fish and wild populations (Clifford et al. 1998; Crozier 1993; McGinnity et al. 2003), which shows that this may also happen with transgenic salmon if it escapes. The environmental impact may depend on the number of escapees, phenotypic characteristics (sexual maturation and survival) and the aquatic biodiversity present in the environment (Black 2001). Escaped transgenic salmon to the environment from commercial activities may create the risk of changing the genetic material (genetic "pollution") of the wild salmon population by mating with wild salmon populations. As the number of escapees has increased up to 0.7 million, they may also compete with the wild salmon for food, habitats and spawning grounds, spread diseases and parasites (Jonsson & Boxaspen 2006).

In the fifth questions students were asked about ethical issues on GM. For most of the students, their belief or religion is not a problem for the use of GM. This can perhaps be either because many students are not religious, that religion/belief is not considered important and/or because they don't see a conflict between their belief and GM. Only 9% of the respondents described themselves as religious, while 59% are atheist or agnostic, and 32% chose not to answer (question 28). Similarly, most of the students disagree that use of GM technology is equal to "playing God". From the responses to the first statement, this is perhaps not surprising. If many students do not see a conflict between religion and GM issues, then the term "playing God" is perhaps not very relevant.

Table 7 indicates that there doesn't seem to be much consensus among the students concerning GM effect on animal welfare in animal production, as responses are more or less evenly distributed on all categories from totally agree to totally disagree. This can be due to different opinions on the matter, or perhaps limited information or focus on this aspect of GM production. In general it seems like these students are slightly positive to the use of GM technology for production of food and animal feed, but more positive to the use of GM technology for medicine production, when considering ethical aspects. Perhaps the benefits of medicine production, like new medicines, cheaper or better availability of medicines, are considered to be more important than the potential harmful effects of the GM technology. Also, the amounts of GM medicine absorbed in the body would be far less than the amounts of GM food. It is also possible that students trust more in the advanced technology and strictly contained facilities of the pharmaceutical industry, using GM microorganisms, rather than the more straightforward outdoor production of food and animal feed involving GM plants and animals.

Even though belief or religion is not considered to be in conflict with the GM technology, there still seem to be disagreement between students to whether this would be "tampering" with nature. Perhaps the concern is more about the risk of disturbing the complexity of ecosystems and the natural balance of nature, like creating GM organisms that spreads uncontrolled in nature or cause extinction of natural species. Also, some genes can be transferred between species, and cause unknown effects. This could be supported by the finding that students seem to believe that the use of GMOs has negative environmental effects (Table 5), hence, can disturb the nature. Also, 11% of the students are members of environmental organizations, showing that many students have a general concern for the environment. On the other hand, respondents in general do not seem to agree that GM technology is unacceptable because of its "unnatural" nature. This can imply that the students accept the use of new advanced technology to make changes in nature, but still are somewhat concerned about the possible effects and this may be related to the acknowledgement of the complexity of ecosystems and the potential long term effects by GMOs.

Table 8 shows that most of the students (average score of 4.7) significantly agreed that the long-term effects of using GMOs have not yet been sufficiently investigated (question 6). Currently, there is a lack of scientific evidence on the long-term effects of GM product on health and environment, which may add to the skeptical perspectives among students or the public knowledge in general. This may be due to the time required, the amount of years needed to study the long-term effects on the environment, animals and humans. Financing a long-term study on the effects of using GMOs is yet another challenge. Possibly, much of the research on GM is financed by the GM industry, which is focusing on the positive effects of GM technology. It is also possible that scientists financed by the industry fail to stay completely objective in their research. On the other hand, the high average score of this statement is probably because students agree that there is a lack of investigation on long-term effects of GMO, since the students only seem to slightly agree that development of GM technology is driven by private companies for profit maximization (see Table 3, statement 4).

The majority of the students (average score of 4.6) agreed that research and information on GMO technology is lacking transparency (see Table 8, statement 3). This means that transparency to the public is required with regard to research initiatives and that information on both GMOs and the technology is needed to be communicated to give increased understanding. Investments in GM technology can be expensive, and possibly it is in the companies' best interests to secure their investments with patents or Intellectual Property Right (IPR), and to keep some secrets to maintain an advantage and avoid or reduce competition. If so, this could perhaps contribute to the lack of information in some aspects of GMOs and the technology.

Media is a strong tool to spread news and influence public opinion toward science and technology (Ho et al. 2007; Ho et al. 2008; Nisbet & Lewenstein 2002; Nisbet et al. 2003; Pew Internet and American Life Project 2006). Many students (average score of 4.3) agreed that media provides information that build fears about GMO without objective and scientific reasons (see Table 8, statement 1). However, this result still suggested that media is a strong tool to spread information and that this information is considered to be biased. In many cases, media companies tend to exaggerate news to increase interest for a case (Slovic 1987), which might increase sales. Also, news about possible harmful effects for humans tend to sell better than news about the positive effects, and this may lead to an increased focus on negative aspects of GMO. Palfreman (2001) stated that media may influence public perceptions because there were pressures on journalists to make news "as simply and dramatically as possible". He also emphasized that good news and bad news affect people at a different level. A study on media content analysis was conducted by Siegrist & Cvetkovich (2001), indicated that news about potential risks tend to be more trusted by public, possibly due to the framing of the news.

It is observed among UMB students that the use of GMOs was most acceptable for saving human lives and production of vaccines to prevent disease, as shown in Table 9. Only 13-17% of the students disagreed more or less on the use of GMOs for saving human lives and production of GM and DNA vaccines to prevent disease. These percentages are considerably low compared with other statements about support on the use of GMOs. It can be argued that DNA vaccines are medical applications which may not be consumed directly by human, but could save lives and contribute to create a better welfare. The second most accepted use of GMOs was for more sustainable meat production using farmed animals, production of animal feed and non-feed. However, production of cheaper food got the least support in this matter. Here, production of cheaper food does motivate some students (average score of 3.2), but is less important with regard to support the use of GMOs.

Overall, Table 10 indicates that there isn't much support on production of GM food assuming appearance (e.g. better color or shape), better taste, cheaper and longer shelf life. If GM food is more nutritious than regular food, students' support on GM food production is relatively evenly distributed among all choices. Still this trait seems to be more appealing than using GM to enhance color, shape, taste, shelf life and lower the prize. It could be argued that nutritional value is a more noble trait to enhance, while the other statements in this question are more about convenience and comfort for the consumer, hence it could also be more "acceptable" to support this kind of GM production. Support for enhancing the appearance, like color or shape, was very low (average score of 2.4) with no support from almost half of the students (45%). This could be a bit surprising, since a lot of people tend to choose nice looking fruits and vegetables in the shop. It could be speculated whether students would still make the same decision if confronted with a real-life situation in the shop, or if they would be more positive to choose a nicer looking product. A chi-square test was conducted to test if study programs (question 26) were independent of responses to statement 4 in question 8 (see Table 10). We found no significant difference ($p > 0.05$), hence study programs do not seem to influence students' support on cheaper GM food.

The majority of the students eat salmon more than once a month, while only 8% never eat salmon, according to their answers to question 9 (see Table 11). The frequency of eating salmon can have some influence on the responses to question 10, where students were asked about the importance of several criteria when buying salmon. For instance if a respondent doesn't like salmon or have food intolerance to salmon, he or she can perhaps be expected not to find any criteria very important, since it is unlikely that they will buy salmon regardless of the criteria. The answer given can in that case deviate substantially from what they would answer if considering a more relevant product.

Interestingly, freshness (average score of 4.4) and sensoric quality (average score of 4.3) were considered to be the most important factor among students when buying salmon (Table 12). Freshness and sensoric quality is naturally important in food as it influences the smell, taste, texture and visual appearance. Price, nutritional content and convenience in preparing/cooking were quite important as well. The latter may be due to practical reasons for young people and/or busy students. Price is expected to be important, and despite students' limited income they perhaps still want nutritious food. It is not considered very important whether the salmon has been fed with GM feed or whether it has been wild caught.

Organic and long shelf life salmon were not important factors for the students when buying salmon. The availability of organic salmon is scarce, and the requirement for fresh salmon with longer shelf life can be limited among students, since frozen salmon with long shelf life is easily accessible everywhere in Norway. Both organic and long shelf life salmon may not give sufficient benefits to the consumer, therefore the students were not concerned about this matter when buying salmon. Organic salmon is salmon that is produced based on the consideration of ecological impacts and high animal welfare. Organic salmon ("økologisk laks" in Norwegian) is seldom available in the Norwegian food stores because of the uncertain market. In Norway, salmon or other fish can be certified and labeled as organic only if it fulfills the requirements of the standards for organic certification by the Norwegian organization Debio/Swedish KRAV (Debio 2001; Debio 2009). Salmar is currently the only representative company that sells organic salmon in Norway. Organic salmon is more expensive than farmed salmon, due to higher production and distribution costs. But there may be relatively small difference between organic and conventional salmon regarding traits like taste, color, nutrition contents and fillet quality. Recent study by Olesen et al. (2010a) on the Norwegian consumers' willingness to pay a price premium for organic and animal welfare-labeled salmon showed a result that consumers preferred organic and Freedom Food salmon to conventional salmon of the same color. In this study, consumers considered color as a more important factor than price when choosing organic or conventional salmon. Also, they were willing to pay more (15%) for organic and Freedom Food salmon if it had the same color as the conventional salmon. Compared to this survey result, the students considered color (and/or other visual appearance) and price as more important factors than if the salmon was organic when buying salmon.

V.2 Transgenic salmon

In this topic of the survey, views were split over whether respondents were willing to eat transgenic fish with regard to if it was more nutritious, that it has improved disease resistance, were environmentally friendly or cheap.

There was a consistent response to question 8 and 11 regarding the support to production of GM food if it was more nutritious. We noticed the responses of question 8, showing little support for more nutritious GM food, and 34% (rating 3 or 4) of the respondents were having a doubt to support (see Table 10). In addition, there were an equal percentage (47%) of non-supportive (rating 1-3) and supportive groups (rating 4-6). Later, this result was confirmed by responses of question 11, where only 23% of the respondents would buy transgenic salmon if it was more nutritious and also 34% respondents were in doubt ("Maybe" response, see Table 13).

The willingness to buy more nutritious and disease resistant transgenic salmon was almost equal, 23% and 21% respectively. But the percentage of the respondents who would not buy a more disease resistant transgenic salmon (43%) was higher than if it was more nutritious (36%). From this comparison, it seemed like nutrition value was a little bit more important than resistant to disease regarding transgenic salmon. This can be due to that better nutrition is giving direct benefits to the consumers health, while less diseases in fish production can save production costs for the producer or -perhaps give the consumer good consciousness because of better animal welfare.

The most common reason for not supporting the use of GMOs was due to concerns that GMO has negative environmental effects. This strong opinion is reflected in question 3 about the safety of using GMO (Table 5) and again confirmed in question 13 (Table 15), on whether the students would buy transgenic salmon if it was more environmentally friendly. With the hypothesis that responses to question 14 are independent of responses to statement 1 in question 7, we found a significant difference in a chi-square test and conclude that on a 5% level, responses are not independent. This indicating a consistent response that students who agreed that the use of GMOs results in no negative environment effects were also positive to buy transgenic salmon if it was more environmental friendly (see Table 16). From Table 16, we find a tendency of increasing percentage of students who want to buy transgenic salmon if it is environmental friendly, with increasing agreement that the safety of using GMOs results in no negative environment effect. Among the students who believe that using of GMOs results in negative environmental effect, 28% of the students are willing to buy environmentally friendly transgenic salmon, showing that environmental effect is important for their choice. On the other hand there are almost 31% of the students that still doesn't want to buy under these conditions. For some reason, they don't want to buy salmon regardless of circumstances, are sceptical to the claim of transgenic salmon being environmentally friendly or perhaps their skepticism for GM food is more important than their environmental concern.

We also tested whether gender influenced the students willingness to buy transgenic salmon if it was more environmentally friendly. We found a strong tendency but not a significant difference ($0.05 < p > 0.1$) in a chi-square test (df = 3, Chi-square value = 7.71). Table 17 indicates that men (53%) were more positive than women (34%) to buy transgenic salmon if it was more environmental friendly. Women are perhaps more concerned about GM food than environmental effects. Therefore, even if the transgenic salmon is more environmentally friendly, many women may still hesitate to buy it. This can be because of women are more concerned about health issues ("you are what you eat"), women's traditional role of preparing food for the family and their role to bear and take care of children.

Transgenic fish can be genetically modified to enhance the quality of the fish such as improved growth rate and cost effectiveness- to be more disease resistance and with the intention to reduce stress (Melamed et al. 2002). The findings in the survey in regard to environmental effects (results from question 3 and 13) shows that there seems to be a concern that transgenic salmon may carry environmental risks. Potential risk of escaped transgenic salmon can be connected to ecological competition or gene transfer to the wild population (Gjedrem & Baranski 2009), due to experiences with domestication of farmed salmon (Smith et al. 2010). The marine environment is vulnerable to pollution, and there are concerns related to the fate of GM DNA in feed, faeces and from dead fish with regard to the possibility of integration and stable expression of intact antibiotic resistant genes (from residual fish feed and faeces) in bacterial fish pathogens and aquatic microbial populations (development of resistance) (Sanden 2004). This concern is also related to consumption of transgenic fish and GM plants. Depleted marine resources and environmental effects (e.g. escapees, fish waste, diseases, parasites, use of antibiotics and chemicals) resulted from fish farms activities have urged to practice a more environmentally friendly fish production.

From the survey results regarding price on transgenic salmon (Table 18), interestingly, respondents fell into three almost equal groups. From the answers, 31% would buy transgenic salmon if it was 20% cheaper, 33% were uncertain (26% answered "Maybe" and 7% answered "I don't know"), and 36% would not buy in this case. Respondents who were uncertain or negative to buying transgenic salmon in this case were asked if they would buy transgenic salmon if it was 30% cheaper. A few respondents changed their opinion to being more positive to buy the product, but there was no statistically significant difference in acceptance found. Price may be an important factor with regard to potential change in attitudes among students towards their willingness to buy transgenic salmon, but it could be that most of this effect is already expressed at 20% reduction in price. In that case, a further reduction in price can't be expected to have a big impact on respondents' opinion. The reasons of their doubt could be the price, personal values and various concerns.

To test if students were consistent in their opinion regarding price, we conducted a chi-square test. With the hypothesis that responses to question 14 are independent of responses to statement 1 in question 7 (see Table 9), we found a significant difference in a chi-square test. From this, we can conclude on a 5% level that responses to question 14 is not independent of responses to statement 1 in question 7, indicating that students who support the use of GMOs for production of cheaper food are also positive to buy transgenic salmon if it was 20% cheaper than conventional salmon (see Table 19).

If transgenic salmon was approved as safe by relevant Norwegian authorities (question 16), the survey result showed that nearly half of the respondents (47%) were willing to buy it (see Table 20). This finding could indicate that respondents of UMB students have less trust in Norwegian Food Safety Authority than Norwegians in general or it could indicate less trust in the authorities with regard to this specific sector compared to other sectors in Norway.

In the case of labeling in question 17, students were relatively united that GM food needs labeling (84%), as shown in Figure 6. It seems like the students have more concerns on the direct use of GM such as in food. Although transgenic salmon is a GM food, the requirement for labeling on transgenic salmon seems to be somewhat lower (69%) than GM food (84%). This can be due to students are perceiving transgenic salmon as different from GM food in general, or perhaps some students fear that labeling of transgenic salmon can lead to injustified reduction in sales (i.e. that consumers skepticism will be exaggerated in relation to the actual risk), hence, some could be willing to accept no labeling. It is perhaps not surprising that students find it less necessary to label salmon that has only been vaccinated with GM/ DNA vaccine (52%), compared to salmon that is itself transgenic. Also it seems like students in general is more positive to medicine, GM and DNA vaccine production, than to GM food production (see Table 9), and hence maybe are more likely to accept no labeling of products when using GM vaccines. However, the Norwegian authorities may label DNA vaccinated fish as a GMO if the DNA vaccines persist degradation and/or retained in the fish (Foss & Rogne 2007).

Table 22 indicates that labeling is also very important if the salmon has been fed with GM plant feed (question 19). The survey resulted in 41% of the students (average score of 4.55) supported a GMO label on salmon fed with GM plant feed. This may due to concerns of fish health, the environmental impacts and that GMOs may have negative implications on animal welfare and on the environment concern. However, labeling is not required in the Americas, but strictly required in the EU for food and feed products containing more than 0.9% of an approved GM ingredient (European Commission 2003). Whereas in the Americas and in the EU, animals fed GM feed are not necessarily labeled as GM products.

GM plants and transgenic salmon can be argued to offer solutions for sustainability in an increased world population and limited marine resources. For example GM plants can be used as an alternative salmon feed ingredient that may reduce the cost for feed production. Transgenic salmon might offer cheaper and more nutritious food that can fulfill the need of the increasing world’s population.

Use of GM plants in salmon feed (Table 21, question 18) to possibly replace scarce marine resources like fish oil and protein got some, but not much support from the students (average score of 3.72). The response is quite similar to the responses in question 7 (Table 9), regarding use of GM in production of animal feed in general, so this result should not be surprising.

To some degree the industry already replace parts of the marine protein and oils in salmon feed with plant sources, and the level of inclusion of plant ingredients are increasing. In the earlier studies, plant sources were known to contain anti-nutritional factors (ANFs) that may negatively affect fish growth and fish feed utilization efficiency (Gomes et al. 1995; Mundheim et al. 2004). However, improved processing techniques have resulted in plant products with increased protein concentration and reduction levels of ANFs in fish diets (Gatlin et al. 2007; Hardy 2010). By using GM plants, there could be other unexpected problems arising, but on the other hand, GM technology may be used to increase the digestibility and nutritional value of plants for salmon feed. Also, salmon are carnivorous, hence many students may find it unnatural to feed salmon with a high level of plant ingredients.

In question 3, the responses showed some ethical concern about GM feed affecting animal welfare, which can also affect their view to the use of GM plants in salmon feed. Still there seem to be a slightly acceptance to use of GM technology for production of animal feed (question 5), but there seem to be a lot of uncertainty among the students regarding these issues.

For the same matter (GM plants) on question 18 and 19, there were a low number of "I don't know" answers (represented by only 2%) on a case of labeling (question 19). It may be due to their determined decision about labeling on GM products. It seems that the students have little knowledge about whether the use of GM plants in salmon feed could replace fish oil from the fisheries, therefore they believed a labeling would be an appropriate precautionary measure. Generally speaking, the importance of labeling is expected to reflect a need for reliable information to avoid misleading marketing. Hence, it may be argued that good labeling regimes are necessary to maintain consumer trust and their option to choose products.

The use of GM in food and feed production is generally not well-accepted not only among European but also Japanese consumers. According to de Melo-Matin and Meghani (2008), this is due to concerns for potential risks on human health and environment, and also that GM may cause negative economical, social and ethical impacts (Wynne 2001).

V.3 GM plants as part of salmon feed sources

The use of fish meal and fish oil in salmon feed need to be reduced if it is a goal that salmon aquaculture should be more sustainable, this is an issue that also is of relevance for attaining responsible fisheries policies to avoid overexploitation of marine resources for short term profit. The sustainable application of GMO in aquaculture is perhaps the key to market acceptance and positive consumer responses. In Norway, feed companies avoid GM plants in fish feed due to consumer skepticism towards products derived from GM. This is also reflected in the survey result (Table 21), where there was relatively low support for using GM plants as salmon feed as replacement for fish oil (23% or average score of 3.72). The large number of "I don't know" answer (13%) on the question regarding GM plants as salmon feed might represent lack of information about the use of GM plants on salmon feed or caused by public debates that didn't seem to persuade them to any particular degree of support on this particular matter. If the large number of "I don't know" answer (13 %) is related to lack of knowledge, may an initiation of more feeding experiments reduce this uncertainty. According to Sanden et al. (2004) should such experiments be carried out on salmon over longer periods, investigation of more tissues, such as blood, spleen and gills, using not only PCR technology but also other method to recognize the impact of GM feed on salmon health.

V.4 Marker-assisted selection (MAS)

A technology called marker-assisted selection (MAS) can be used to breed salmon to improve disease resistance and so that salmon can grow more efficiently. By using information about a genetic marker, disease resistant fish can be identified and selected for breeding without having deliberately infected a lot of test fish first. In question 20, students were asked about acceptable methods for improving growth and/or disease resistance in salmon. Table 23 shows that there is a high level of support for all methods except for the use of transgenic salmon (average score of 3.3). The difference in level of support is relatively moderate between traditional selective breeding without genetic modification (average score of 5.0), MAS combined with traditional selective breeding (average score of 4.9) and MAS technology (average score of 4.8). Obviously, there were more students that fully accepted traditional selective breeding (50%), compared to the other methods (39% and 34%, respectively) as promising alternative to GM. Traditional selective breeding has been known to bring considerable improvement in agriculture and aquaculture, and has been used for centuries, hence it might be considered as a very safe and sufficiently good method. MAS is obviously much more acceptable than transgenic salmon, but still less acceptable than traditional selective breeding. It can be that students are more uncertain about the risks of using this method, perhaps due to lack of knowledge or experience. On the other hand, the potential risks of using MAS should still be present when used in combination with traditional selective breeding, and still this option had almost as high support as traditional selective breeding. The question was about how acceptable the different methods were, not which are best or should be recommended. It is possible that some students gave less support for MAS used alone, because they believe that it is not suited to replace traditional selective breeding, even if they find the method itself fully acceptable. Use of transgenic salmon got less support than the other methods, with answers more or less scattered over all categories, showing more concern regarding this method. This response is somewhat similar to the response to whether GM technology is ethically unacceptable in food production (average score of 3.1, see Table 7), and hence, not very surprising. In another related question, the support for using GMOs for more sustainable meat production by using farmed animals (e.g. more efficient production and less animal disease, see Table 9) are a bit higher, but still not very different. Responses to these questions seem to be quite consistent.

From the questions about transgenic salmon, we found that the willingness to buy transgenic salmon that is more nutritious (Table 13), more disease resistant (Table 14) or cheaper (Table 18) is quite low, but there isn't much agreement between respondents, since answers seem to be scattered between all options. This again, support the finding that there is disagreement about the use of genetic modification (transgenic salmon) to improve growth and/or disease resistance of farmed salmon to get cheaper salmon or salmon that are healthy to eat, hence, much consistency in answers to these questions.

V.5 Overall survey

Distributing the survey invitation and data collection went well but the number of respondents was not entirely satisfying. The low response rate of about 18% in this survey, increases the risk that the respondents do not represent UMB student fully. A prize incentive was used in an attempt to encourage students to participate and to complete the scientific survey. The incentive was not enough to motivate the majority of the students to take the survey.

There may be some reasons for the students did not participate in this survey. Since the participation on this survey is voluntary, many students may skip it because of low interest in the topic, either because they consider it as not important or lack of time. At the time the survey was conducted, some students might be absent from the university, for instance due to illness or travelling, or perhaps they were unaware of the survey. The latter could be for instance because they did not read their e-mail in time or the e-mail invitation was sent to an inactive/unused e-mail address.

Some reasons can be expected to be more or less coincidental in the way they affected the survey population, and should not impose a major impact on the results. On the other hand, some reasons can be expected to have some effects. It is possible that the respondents of this survey are more interested either positively or negatively in GM topics, than the average of UMB students. If so, I might expect more of the answers to be "positive" or "negative", rather than neutral to many questions on this topic. Although interest in the topic does not imply that they are either positive or negative to GM, it is likely that they have an opinion on many of the questions, and it seems plausible that students with very positive or negative views on GM technology would be more interested in the topics than the average UMB students.

There are some drawbacks and benefits of different methods for conducting a survey. In this case, where students were invited through e-mail and the response is given through a computer, a large number of students can relatively easy to reach. It will probably be difficult for the respondent to ask any questions to clarify uncertainty about the survey questions, and hence it might be expected to be a higher percentage of "I don't know" answer, especially if there were complicated questions or topics, compared to a survey conducted face to face (with possibility to clarify questions). The latter would, on the other hand, be much more time consuming for a large number of respondents. It is possible that a respondent replying face to face with a person, could tend to answer more similar to common belief for instance in questions about ethics on GM, to avoid any unpleasant confrontation to personal views. In that case, the more anonymous reply through a computer can be expected to better reflect the diverse opinions among the respondents. On the other hand, it can perhaps be easier to skip or answer questions arbitrarily on a computer, rather than responding face to face with a person.

This study found an interesting feedback with regard to technology preference towards GMO products in aquaculture. The students' knowledge may have more or less influence to their attitude towards the application of GMOs in aquaculture, whether it is common knowledge or scientific-based knowledge.

Results from research may influence these students' opinions or attitudes in the future, as well as positive or negative news or stories from the mass media. It is not uncommon that people change or moderate their opinion and attitudes according to the age and experiences. Hence, we cannot assume that these students will have the same opinion in the future, but it is likely that their future attitudes and values will be somewhat similar.

In Norway, we may not find the development of GM products, and hence any change would be towards more research on the possible use of GM products. Considering these students' attitudes, it is likely that they would accept more the use of GM technology for medical purposes or pharmaceutical industry, while still being cautious when it comes to production of GM food and GM feed.

The collaborative research in ELSA/FUGE project "Stimulating sustainable innovation in aquaculture" is an excellent way of working together to address related common concerns raised by genetic engineering technology and its application on aquaculture industry. The result of the surveys may be of interest to scientists, policy makers, consumers, food producers and industries as well as students who will soon finish their study and become researchers, producers or decision makers at their work place in the future.

VI. CONCLUSIONS AND IMPLICATIONS

The majority of the UMB students seem familiar with genetic modification and GMOs, knowing the definition, method and purpose of the technology. The students concerns regarding the safety of using GMOs are particularly related to environmental impacts, but they also show some concern for human health, animal welfare and ethical concerns. The majority of the students encourage the reduction of the risk of GM applications by doing more research on GMOs and that there is a need for seeking expert advice on risk issues, they also acknowledge the need for more transparency surrounding the production of GMOs and the GM technology, also the need for improving communication between scientists and the public was emphasized. Students were uncertain whether we can gain enough knowledge to reduce all possible risk of using GMOs since the consequences of using GMO is uncertain and the ecosystem they will be used and released into are too complex.

When considering ethical aspects on GM technology, it is a common view that application of GMOs are “tampering” with nature, but only to a small extent was this view related to belief of religion. In general it seems like these students are slightly positive to the use of GM technology for production of food, animal feed and non-feed, but more positive to the use of GM technology for saving human lives (e.g. medicine and vaccine production) and for production of vaccines to prevent disease.

Students agree that there is a need for more studies of the long term effects of using GMOs, and more transparency about research on GMO technology. Media is not believed to give an objective presentation about GMO, but rather to provide information that build fears about this topic. Use of GMOs to enhance the appearance or produce cheaper food hasn’t much support among the students. There is some support on production of GM food to enhance nutrition value but less to enhance appearance (e.g. better color or shape), taste, price or shelf life.

When buying salmon, freshness and sensoric quality is considered most important, while price, nutritional content and convenience in preparing/cooking were important traits as well. Interest in organic or long lasting salmon is low among students.

Willingness to buy transgenic salmon that is more nutritious or disease resistant is low, while students seem to be more positive if it is more environmental friendly. Students who agreed that the use of GMOs results in no negative environment effects were also positive to buy transgenic salmon if it was more environmental friendly. There was a tendency for men to be more positive than women towards buying transgenic salmon if it is more environmentally friendly. Almost 1/3 of the students are willing to buy transgenic salmon if it is 20% cheaper than conventional salmon, but any further reduction in price has only minor effect. Students who support the use of GMOs for production of cheaper food are also positive to buy transgenic salmon if it was 20% cheaper. Students' study programs do not seem to influence students' support on cheaper GM food.

Nearly half of the respondents (47%) were willing to buy transgenic salmon if the Norwegian Food Safety Authority has approved it as safe. This finding could indicate that respondents of UMB students have less trust in Norwegian Food Safety Authority than Norwegians in general or it could indicate less trust in the authorities with regard to this specific sector compared to other sectors in Norway. When it comes to labeling of GM products, students are quite united that GM food needs labeling, while there is somewhat less support for the need for labeling of transgenic salmon or when using GM vaccines in salmon. There is only a limited support for replacing scarce marine resources with GM plants as salmon feed, and most students requested a GMO label on salmon fed with GM plant feed.

Students have highest support for traditional selective breeding as an acceptable method to improve growth and/or disease resistance of farmed salmon. Marker-assisted selection (MAS) and MAS combined with traditional selective breeding also got high level of support, in contrast to the use of GM for developing transgenic salmon.

Future studies should investigate more specifically on the sustainable aspects of GMOs in aquaculture and linkage between GM innovations and IPR strategies. New studies could influence the national legislation regulating the use of GMOs in aquaculture in Norway in order to explore the benefits of using GMOs as sustainable solutions in aquaculture industry. It may allow for an "open door" to future practices of appropriate GM technology confirmed by policy makers as part of sustainable solutions in aquaculture practices.

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VIII. APPENDIX