Food Quality: A comparison of organic and conventional fruits and vegetables.

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Why are there so many songs about Rainbows and what's on the other side?
Rainbows are visions but only illusions, and rainbows have nothing to hide.
So we've been told, and some choose to believe it.
I know they're wrong wait and see.
Someday we'll find it, the rainbow connection.
The lovers, the dreamers, and me.

– Kermit the Frog

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2. Abstract

This paper addresses food quality of organic and conventional fruits and vegetables. A literature review was conducted to summarise and discuss the findings of research comparing food from the two production systems. A difference in food quality was found for nutritive value (vitamin C) and toxicity (nitrates and pesticides). A survey was performed to evaluate consumers' reasons for purchasing organic food and their understanding of the term food quality. The primary reasons found, in this survey, for buying organic food were environment, health and taste. Definitions of food quality were varied. Most responses related to sensory, safety and nutritive parameters. A market supply experiment was conducted to analyse the difference in specific internal and external quality parameters for organic and conventional Golden Delicious apples. Significant differences were found for the sugar-acid ratio, volume and colour (no difference was found for sugar, acid, pH, dry matter and firmness). Near infrared (NIR) spectral analysis was performed to evaluate this technology's ability to predict food quality and to differentiate between organic and conventional apples. NIR spectra could weakly (74% correlation) predict sugar content in apples. Potential discrimination of organic and conventional apples was shown for our data, however, our statistical model could only classify at a 25% significance level. We conclude that there are differences between organic and conventional foods for some parameters, however, quality is influenced by factors other than organic regulations such as cultivar, climate, soil type and storage conditions. We have found enough evidence to support a significant difference in food quality in the findings of research and in the preferences of our survey respondents.

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4. Introduction

> *Since the 1920s, when chemical fertilizers were first used commercially on a large scale, there have been claims that agricultural chemicals produce less healthful and less nutritious food crops. By the 1940s, the organic farming movement had begun, in part due to this belief that food grown using more traditional, chemical-free methods was more healthful. Foods grown by these methods came to be known as "organic."*
>
> Worthington, 1998

Today, the organic market is a growing sector of the agriculture industry in many parts of the world, and it is possible to find organically produced food in most supermarkets in Europe and North America (David Suzuki Foundation, accessed 2002). However ideal the goals of and production methods used in organic farming sound, can one really tell that organic food is "better" than conventional food? We found that a substantial number of students from our respective universities buy organic food because they think it is of higher quality. When we asked students what they mean by food quality, they provide varying answers, if they provided answers at all. It is quite obvious that these consumers are lacking good and objective information about food quality and its relation to organic and conventional products. To illustrate this fact, a survey was conducted that provides a general overview of students' reasons for consuming organic food and their knowledge regarding and food quality. This survey will be used as a starting point to direct our research into the differences in quality between organic and conventional food.

Food quality in itself is very difficult to define as it depends, to a certain extent, on one's personal tastes and priorities. Examples of parameters possibly involved are taste, appearance, firmness, juiciness, nutrient content, concentration of toxins and microbial contamination. A literature review of some of these parameters is presented this paper. The literature survey covers differences between food from organic and conventional production systems, and how these differences could effect health. This paper will only deal with the parameters that appeared to be the most important to consumers. The taste, nutrient content, heavy metal and environmental pollutants, fertilisers are the most widely studied.

Original research was conducted to test the difference in quality between organic and conventional apples. This experiment tested the food quality parameters: sugar and acid content, firmness, dry matter, volume and colour.

The results of the survey, literature review and experiment are combined to develop final conclusions about whether differences in food quality exist between organic and conventional food.

Differences between organic and conventional farming practices.

One of the main differences between organic and conventional farming is the use of synthetic chemical fertilisers. Conventional farming allows the use of synthetic fertiliser as well as manure, compost, sewage sludge and other soil amendments. Most certified organic farming only allows the use of manure and compost and other soil additives such as bone or blood meal. The synthetic N, P and K that is prohibited in organic farming, normally provides nutrients that are readily available to the plants, whereas, in manure, some of the nutrients have to undergo chemical transformations before they can be utilised. Therefore, both organic and conventional farming systems can provide the essential macronutrients to the crops, only their source and availability for uptake are different.

The second major difference related to food quality between the two systems is the use of pesticides and herbicides. Conventional farming once again allows the use of any product available on the market (not forbidden by law), while organic farming allows only a few pesticides, and must therefore, rely largely on the use of management practices, such as tillage and crop rotations, to overcome pest and weed problems. The pesticides permitted in organic farming are those that are believed not to leave any residue on the products. For instance, in England, the only pesticides approved by the UK Soil Association are:

1. Copper ammonium carbonate, copper sulphate, copper oxychloride (however these are being phased out because there is evidence that copper residues were found in vegetables treated with those chemicals)
2. Sulphur

3. Rotenone (low levels of this chemical, which is toxic to fish, have recently been found in honey from bees (Johnston *et al.*, 1999)
4. Pyrethrum (residues were found in snakes whose habitat has been treated with this product (Johnston *et al.*, 1999)
5. Soft soap

(Williams *et al.*, 2000)

Since it has recently been established that some of these chemicals do leave residues on food, they are likely to be prohibited in the future. The use of these pesticides could lead one to question whether organic food is really free of chemical residues. This paper will try to determine whether pesticides residues were found on organic and conventional fruits and vegetables, and if so, whether they are within the acceptable limits set by the UK Food Standard Agency (FSA). It is important to distinguish between three values considered by the FSA:

1. MDL: the Minimal Detection Limit. Levels of pesticides below this limit cannot be detected by the methods and apparatus used by the FSA. (Williams *et al.*, 2000)

2. ADI: Acceptable Daily Intake. For each contaminant, this is the highest value for which no adverse effects were observed during experiments on animals, divided by 100. Dividing by 100 corrects for the fact that the initial value might be slightly inaccurate (because only a certain amount of different doses were administered to animals, and therefore the exact threshold cannot be known). Humans can typically be up to 10 times more sensitive to certain chemicals than animals. (Williams *et al.*, 2000)

3. MRL: Maximum Residue Limit. Maximum level of each contaminant in food considered suitable for consumption. (Williams *et al.*, 2000)

Definition of Organic Farming

Organic farming refers to a particular farming system that uses organic manures, limited range of naturally derived chemicals. Organic farming uses no growth regulators, artificial feed additives, biocides or synthetic chemical sprays (Beharrell and MacFie, 1991). Overall, the goal of organic farming is to use agricultural methods that have the smallest impact on the environment and provide the largest benefits to people (The David Suzuki Foundation, accessed 2002). However, different people and organizations in different parts of the world have slightly different definitions of organic farming. For instance, the United States Department of Agriculture formally defined organic farming in 1981.

> *Organic farming is a production system which avoids or largely excludes the use of synthetically compounded fertilisers, pesticides, growth regulators and livestock feed additives to the maximum extent feasible. Organic farming systems rely on crop rotation, crop residues, off-farm organic wastes, mechanical cultivation, mineral bearing rocks and aspects of biological pest control to maintain soil productivity and tilth to supply plant nutrients and to control insects, weeds and other pests.*
>
> Beharrell and MacFie, 1991

The European Union has published its own definition of organic farming in the document "Organic Farming: Guide to Community Rules".

> *To define the concept of organic farming, we may refer to the definition developed by the Codex Alimentarius, on the basis of contributions from experts from all over the world. According to the Codex, organic farming involves holistic production management systems (for crops and livestock) emphasising the use of management practices in preference to the use of off-farm inputs. This is accomplished by using, where possible, cultural, biological and mechanical methods in preference to synthetic materials.*
>
> European Communities, 2000

Woese *et al.* (1997) has defined organic products as all products which are produced under controlled cultivation conditions in line with the provisions of the EC Regulations on organic farming (for products of plant origin (Verordnung (EWG) 2092/91)) and its supplementary statutory provisions or the guidelines of the various recognised farming associations (holding organisation: International Federation of Organic Movements). Woese *et al.* (1997) continues to define organic products as those grown without the aid of chemical-synthetic pesticides and largely without the use of readily soluble mineral fertilisers within a diverse range of crop rotation and extensive soil tillage.

Certified organic farming requires the farmer to follow strict regulations to maintain "organic" certification. Certification and labelling are used to create a differentiated consumer product. There are several different bodies world wide, setting organic standards. These bodies include: The Soil Association, Organic Farmers and Growers Ltd, UK Register of Organic Food Standards (UKROFS), and the International Federation of Organic Agriculture Movements (IFOAM).

Definition of Food Quality

Consumer satisfaction is directly related to product quality. However, quality may be defined in several different ways. From all the different definitions different measurement methods arise, as well as different theories about how quality actually relates to consumer satisfaction (Schewfelt, 1998). Fruit and vegetable quality changes as these products are passed along the distribution chain, and the perspective of handlers or consumers depends on their position in this distribution chain as well as their personal tastes (Schewfelt, 1998).

Abbot (1999) defines the term quality as the degree of excellence of a product or it's suitability for a particular use. She describes quality as a human construct comprising many properties and characteristics. This quality of produce encompasses sensory properties (appearance, texture, taste and aroma), nutritive values, chemical constituents, mechanical properties, functional properties and defects. Abbot (1999) states that quality can be defined from either a product orientation or a consumer orientation.

From the consumer orientation, which is directly linked to consumer satisfaction, each person passes judgement, and each has his or her own set of quality or acceptability criteria. These criteria are often based on personal expectations and preferences (Abbot, 1999). People use all of their senses when evaluating quality. They use sight, smell, taste, touch and even hearing. The five senses form sensory inputs such as appearance, aroma, flavour, hand-feel, mouth-feel and chewing sounds. This is the information that determines the quality judgement of the acceptability of the fruit or vegetable (Abbot, 1999). Consumer-oriented studies are aimed at predicting a product's 'success' on the market. They require a good understanding of consumer behaviour and are more directed towards human perception parameters than product-oriented studies are, and they try to determine acceptability and willingness to purchase from the consumer's point of view (Schewfelt, 1998). However, this acceptability and willingness to purchase vary greatly between different groups of people, and even within the same person, depending on his or her mood and needs (Prussia and Schewfelt, 1993 in Schewfelt, 1998). Also, parameters that are important to consumers may be difficult to measure accurately and may vary greatly during handling and storage (Schewfelt, 1998).

Product-oriented quality, on the other hand, includes various attributes used to evaluate the effects of post-harvest treatments (handling techniques, storage conditions, etc.) and is more easily defined and understood than consumer-oriented quality. The quality changes can be plotted as a function of time and be associated directly with the post-harvest treatment being studied (Schewfelt, 1998). Product-oriented quality is normally measured using scientific methods and analytical instruments and may therefore be more accurate and easily analysed (VanTrijp and Schifferstein, 1995 in Schewfelt, 1998). However, not all parameters can be measured with the same ease. For example, appearance is more easily assessed than texture, which is more easily assessed than taste. Therefore, appearance evaluation normally predominates in importance over texture and taste when it comes to determining the quality of a product. This creates biases in the 'true' quality of products (Schewfelt, 1998). Also, even with the product-oriented assessment in hand, it is very difficult to determine which quality differences will influence consumer behaviour and how. Thus product-oriented studies are not very efficient at predicting a product's performance on the market (Schewfelt, 1998). It can be concluded that both approaches to quality have their strengths and limitations.

When trying to measure food quality the choice of what to measure, how to measure and what values are acceptable are determined by the person or institution requiring the measurement. Consideration of the intended use of the product and of the method of measurement, available technology, economics and often tradition play a role in how food quality is assessed (Abbot, 1999).

One way to evaluate food quality is by using physical or chemical analyses. There is some debate about whether these analyses sufficiently define food quality. This has lead to some investigation of holistic methods concerning investigations of the product itself, such as the determination of electrochemical parameters, the measurement of low level illuminescence, the observation of storage quality, or picture-developing-methods (Plochberger *et al.*, 1992). Other methods of investigation of food quality are food preference and sensory evaluation of food by test panellists or untrained consumers (Plochberger *et al.*, 1992). Feeding experiments using animals can also be used to determine food quality (Plochberger *et al.*, 1992). When the above procedures are used with fruits and vegetables they are in effect defining the influence of different farming systems and post harvest storage and handling on the quality of produce (Plochberger *et al.*, 1992).

Lampkin (1990) calls food quality a very ill defined concept. Taste and appearance are personal assessments, and ultimately the individual consumers will have to determine themselves if they prefer either organic or conventionally grown food on the basis of their own experience. Therefore, laboratory analysis can only provide a partial description of food quality.

The discussion on food quality is often limited to one of legal standards for the upper safe limits of microbial contamination or the lower limits of vitamins, minerals and trace elements in a product as it leaves the factory. This ignores the completion of the food chain from producer to consumer and therefore may not measure food quality at the consumer endpoint of the food supply chain (Taeymans, 2000). As stated earlier, quality for the consumer is subjective. Consumers measure food quality using visible features, such as the “pleasure” attributes of the product, and their awareness of invisible qualities, such as microbial and toxicological safety and nutritional value (Taeymans, 2000). The role of the food processor or marketer is to meet consumer expectations of quality, whether visible or invisible, through appropriate quality control and quality management methods (Taeymans, 2000).

Some of the most popular quality definitions are listed below.

As properties of product:

> Quality – that which belongs to something and makes or helps to make it what it is; basic nature, characteristic attribute. (Webster's New 20th century dictionary in Martens and Martens, 2001)

As subjective and intuitively evaluation in *goodness / excellence* category:

> Quality is any character or characteristic which may make an object good or bad, commendable or reprehensible. (Webster's New 20th century dictionary in Martens and Martens, 2001)

As compilation of two first meaning with connection of meeting human needs:

> Quality is the ability of a set of inherent characteristics of a product, system or process to fulfil requirements of customers and other interested parties. (ISO, 1999 in Martens and Martens, 2001)

As combination of product characteristic and subjective perceptions in experience:

> "Quality is not thing, it is the event at which awareness of subject and object is made possible" (Martens and Martens, 2001)

Elements most often used in defining food characteristics:

Functional: food properties appropriating to requirements of handling, storage and processing
Sensual: include characteristics as aroma, flavour, appearance, texture
Nutritional: nutrient contents, meet with diet requirements

Now some consumers add more elements to describe food quality:

Biological: include food influence on human physiology, ability to maintain human health
Ethical: evaluation of food in social, environmental and political aspects. They are connected with animal welfare, unpolluted environment, *fair trade*

Authenticity: less processed food, less additives changing products, *real food* (Rembiałkowska E., 2000, Diver S. 2000)

Factors affecting the quality of crops.

The quality of fresh fruit and vegetables depend on their quality at harvest, which changes during the storage. The most important predictors of food quality in vegetables and fruit quality are genetic factors. The major preharvest factors, which impact on the quality of vegetables and fruit are climate, soil and management practices.

The crop variety and genetic properties have a major impact on vegetable and fruit quality. Nutritional value, taste, flavor and appearance are all related to the variety of crops. The variation in these elements of food quality is very high. For instance, the fluctuation in the content of beta carotene, between different carrot cultivars, can reach nearly 300% (Knorr and Vogtmann, 1983). The firmness of tomatoes, measured as compression, varies up to 165 %, and tomato flavor varies up to 106% (Salunke and Desai, 1998).

The most important climate factors affecting plant quality are light intensity, temperature and water availability. The influence of climate on nutritional value of vegetables and fruit is reported in Salunke and Desai (1998), Weston and Barth (1997) and Knorr and Vogtmann (1983). They report that higher light intensity increases vitamin C, B_1 and beta carotene content in vegetables and fruit. Higher light intensity has a larger influence on leafy green vegetables. High temperature reduces vitamin C content in grapefruit and drought reduces vitamin C in leeks and broccoli. Lee and Kader (2000) Sams (1999) and Kays (1999) discuss impacts of climate on sensual perception. Light intensity during maturation of fruit influences coloration. Excess sunlight, above the wavelengths used in photosynthesis, and low temperature, decrease firmness and raise the number of defects in apples. Hail and high wind also cause defects in vegetables and fruit, particularly leave loss in leafy vegetables.

Fertilization the most important and controllable factor affecting nutritional value of fruit and vegetables. The type and value of fertilizer and the level of application, directly influence the level of plant available nutrients and indirectly influence plant physiology and chemical content. A lot of research has found differences in nutrient levels in vegetables and fruit, grown at various levels of nitrogen fertilizer. These studies compare various levels of artificial, organic and mixed fertilizer. However, very few studies compare the effect of fertilizer on nutritional quality of vegetables and fruit in organic and conventional production.

A positive correlation between protein content and level of applied nitrogen fertilizer was found (Knorr and Vogtmann, 1983 and Weston and Barth, 1997). However, the quality of protein, measured as a ratio of essential amino acids (EAA), had been shown to decrease with increasing of applications of nitrogen fertilizer in some crops (Knorr and Vogtmann, 1983; Weston and Barth, 1997 and Rembiałkowska, 2000). In other crops no change in protein levels have been reported (Knorr and Vogtmann, 1983 and Weston and Barth, 1997). Fertilization increases the concentration of nitrogen compounds, except for free amino acids, in crop plants. This also explains the higher content of nitrates in vegetables (Weston and Barth, 1997 and Rembiałkowska, 2000), especially for leafy green vegetables (Lee and Kader, 2000).

Other examples of nutrient compounds are carbohydrates and fibre. Some research has found increased levels of nitrogen fertilizer to decrease the content of glucose in vegetables (Knorr and Vogtmann, 1983) and fibre in amaranthus (Sams, 1999) and cabbage (Weston and Barth, 1997). This is consistent with the influence of nitrogen fertilizer on the protein-carbohydrate ratio. Carbohydrates compete with protein synthesis for photosynthates, the products of photosynthesis. Higher levels of nitrogen lead to a higher protein-carbohydrate ratio and, therefore, a decline the carbohydrate content (Salunke and Desai, 1998).

The level of nitrogen influences the vitamin content of vegetables and fruit. Research has focused on vitamin C because it is one of the most important vitamins in human nutrition. A negative correlation between vitamin C content and the level of applied nitrogen fertilizer is often reported (Weston and Barth, 1997 and Lee and Kader, 2000). Weston and Barth (1997) reported that nitrogen fertilization increases beta carotene in vegetables. This is due to the connection between nitrogen and beta carotene in plant metabolism (Weston and Barth, 1997).

Some authors have mentioned the influence of nitrogen fertilizers on sensory evaluation, another parameter of quality. Sams (1999) reported that increasing nitrogen decreases firmness. This is an undesirable sensory parameter in fruit and vegetables. Several studies have found increasing of levels of nitrogen fertilizers to decreases taste (Knorr and Vogtmann, 1983; Lee and Kader, 2000 and Mattheis and Fellmann, 1999) and volatiles, including aromatic compounds (Weston and Barth, 1997).

The other important minerals for plant growth in fertilizer are P, K, Ca, S. Little research has been conducted on the effect of minerals on crop quality. SSC in tomatoes increases with increasing phosphorus content (Weston and Barth, 1997). Phosphorus shortage decreases the firmness of fruit (Sams, 1999) and calcium increases firmness (Weston and Barth, 1997). Potassium causes a decline in the firmness of fruit (Sams, 1999) and rise of total and titratable acid in tomatoes (Weston and Barth, 1997). Other findings report that excess sulphur decreases the "green" aroma and increases the pungency and sulphur flavor in onion (Mattheis and Fellmann, 1999).

Pesticide and preservative residues influence both positively and negatively the nutritional content, shape, coloration and flavor of vegetables and fruits. These effects are presented in following table (Table 1).

Table 1. Influence of chemical controls on nutrition value and appearance of fruit and vegetables.

Chemical controls	Cultivar	Characteristic	Effect
N-dimethylaminosuccinamic acid	blueberries (1)	Firmness	+
Gibberellic acid	Tomato (1) Grapefruit (1) Pear (2) Grape (2) Apricot (2)	Firmness Colour Size Size Weight	+ -/+ - + +
Ethephon	Tomato, muskmelon (1) Muskmelon (3) Apple, orange (2) Mung bean sprout (2)	Firmness Flavor (measured one day after harvest), Sweetness (also after two days) Pigmentation Shape	- - -/+ -/+
Abamectin and fenbutatin oxide	Strawberry (3)	Sweetness, flavor	+
Dichloroprop	Apple (2)	Colour	-/+
Amitrol	Potato (2)	Shape	-
Fungicides (2,4-D and dicamba)	Tomato (2)	Shape	-
Metribuzin	Potato (4)	Nitrogen, protein Nitrate level	+ -
Clomazone	Squash (4)	Carotenoids	-
Ethalfuralin	Squash (4)	Coloration	-
Fungicides	Apples (3)	Volatile compounds (flavor)	-

+ effect in plus, - effect in minus, -/+ caused changes

1 – Sams (1999), 2 – Kays (1999), 3 – Mattheis and Fellmann (1999), 4 – Weston and Barth (1997).

Maturity at harvest can significantly effect the vegetable and fruit nutrient content. Time of harvest particularly influences the vitamin C concentration in fruit. Some fruit, like apples and apricots, when immature, contain less ascorbic acid than when fully mature. However, the content of vitamin C, in mangos, is negatively correlated with maturity stage (Knorr and Vogtmann, 1983).

During ripening, components that cause flavor development are accumulated in fruits. Fruit harvested at early stages of maturity have less flavor than those harvested when more mature. Also, immature fruit that ripen in storage, have poor taste and aroma when compared to fruit that is harvested when ripe (Mattheis and Fellmann, 1999)

Firmness of fruit is negatively correlated with the stage of maturity. The best examples are apples, pears and peaches, which soften during the ripening. In contrast, some green vegetables such as asparagus, broccoli and peas accumulate fibre overtime and becoming tough (Sams, 1999). Differences in storage degradation between organic and conventional produce were compared in eight studies. These studies suggest better or equal preservation of organic and conventional food (Heaton, 2001).

Agricultural practices are different organic and conventional cultivation. The most important differences are fertilization practices and chemical controls. This could cause different quality between products from the two production systems. Organic products may contain more protein and vitamins and less chemical residues. Production method causes differences in sensory parameters, however, it is difficult for consumers to detect or evaluate these differences. The differences in nutrient content and sensory parameters are small in comparison with differences caused by climate and soil type. Yet, management practices, between cultivation systems, can still have an impact on the overall food quality of fruits and vegetables.

5. Literature Review

Introduction

STUDY TYPES

So far, over 180 studies attempted to compare in some way organically and conventionally produced food (Gilbert and Shepherd, 1985). However, the products examined are various (vegetables in general, specific vegetables, cereals, meat, milk, beer, honey, etc.) and so is the scientific rigourousness and the quality and objectivity of the data. These studies can be sorted into three different categories (Woese *et al.*, 1997). Here is a brief description of each category of study:

1. Market-oriented supply study: This kind of study monitors the marketed produce available to consumers by collecting food samples from shops selling organic and conventional food. The limit to this kind of study is that the producer is unknown, and consequently the information about growing conditions (climate, soil type, management practices, cultivars, etc.) is not available. Furthermore, the samples differ in ripeness and variety, which can seriously affect the quality parameters (Woese *et al.*, 1997).
2. Surveys: These are conducted on products from selected farms, and thus neighbouring farms can be chosen in order to make sure that the climate is the same and that soil types are somewhat similar. However, it is difficult to select truly representative farms and fields for both organic and conventional farming practices and the accuracy of the information given by farmers cannot be verified (Woese *et al.*, 1997).
3. Cultivation tests: This is the most accurate form of comparative study, and it attempts to determine whether food from different forms of production show distinctive differences in quality and if so, to which factors and methods of productions these differences can be attributed. However, the results of these studies only apply to specific locations and management practices (Woese *et al.*, 1997).

Each of these three methods has its own limits, so in order to achieve complimentarity and to have an objective and significant comparison of organic and conventional products, it is necessary to examine studies of each type (Woese *et al.*, 1997).

LIMITATIONS

The limitations to each study method must be taken into account. For instance, in order to produce significant results, comparisons should only be made using identical strains of plants managed under similar conditions to keep genetic and environmental variations at a minimum (Williams *et al.*, 2000). Plants should be cultivated in similar soils under similar climatic conditions, be pre-treated similarly, sampled at the same time, and analysed by accredited laboratories employing validated methods (Kumpulainen, 2001). Most studies done so far show a lack of rigorously controlled conditions and extensive background information about the site of study (Williams *et al.*, 2000). Many studies involve only a very small number of samples, which leads to low reliability of results and does not allow generalisation, and provide no details about variety, age and degree of ripeness of plant samples, even though these factors seriously influence the concentration of different ingredients in samples, and can also alter the effects of the various cultivation forms (Woese *et al.*, 1997).

These studies were performed on a great range of different crops. It is thus not easy to draw conclusions about vegetables or fruits in general. This is more of a problem for fruits than for vegetables. A relatively large number of studies have been performed on vegetables. Whereas for fruits, only very few studies have been done, and most were concentrating on apples, strawberries, oranges and lemons only. This does not allow for generalisation for fruits in general (Woese *et al.*, 1997).

One must also be careful in comparing studies done very far apart in time. Organic agriculture has not change much over time with respect to the use of chemicals, conventional agriculture practices have changed significantly in the last century. It is therefore important to take these changes into account when comparing studies (Williams *et al.*, 2000).

When talking about whether or not organic and conventional farming systems lead to differences in food quality, one can only talk about the methods of fertilization and pest and weed control. As far as fertilisation is concerned, it is very difficult to compare different studies and come up with significant results. A study comparing a high input organic production and a low input conventional production will probably give very different results from a study comparing a low input organic farm and a high input conventional one (Gilbert and Shepherd, 1985). All studies have been done using different levels of fertilization on different soils, and so we must be very careful in comparing them. In the end one must compare specific methods of fertilization rather than organic or conventional farming as a whole. For the pesticides and herbicides, we must also take into account whether or not organic farms use permitted pesticides, and what pesticides are used in both systems. Once again, the results will be related to which pesticides are used and in what quantity rather than the total farming system.

Finally, many parameters can be compared. This adds to the difficulty of comparing different studies, in that even though some of them were done in similar conditions, they do not compare exactly the same parameters. Here are the parameters that were studied and that will be examined in this paper:

1. Protein
2. Sugar, acid and dry matter
3. Vitamins
4. Minerals
5. Toxins
6. Chemical controls pesticides
7. Heavy metals
8. Nitrates
9. Microbial contamination
10. Secondary Metabolites

Before presenting our literature survey here is a summary of the findings of Woese *et al.* (1997) and Heaton (2001). It does not include taste tests, but is a good introduction to nearly all the other parameters that will be examined subsequently in this report. Heaton (2001) only reported the studies that he deemed valid. The criteria he used for rejecting papers were insufficient duration, incorrect or unknown practices, no relevant comparison and republished studies.

Table 1. Number of studies of organic crops shown to have higher, lower or equal nutrient content compared with conventionally grown crops. (Woese *et al.*, 1997)

Nutrient	Higher		Equal		Lower	
Reviewer	Woese	Heaton	Woese	Heaton	Woese	Heaton
Protein quality	3	–	0	–	0	–
Nitrate	5	0	10	2	25	14
Vitamin C	21	7	12	6	3	0
B-carotene	5	–	5	–	3	–
B-vitamins	2	–	12	–	2	–
Calcium	21	–	20	–	6	–
Magnesium	17	–	24	–	4	–
Iron	15	–	14	–	6	–
Zinc	4	–	9	–	3	–
Minerals	–	7	–	6	–	1
Dry Matter	–	10	–	8	–	1

Taste

Basker (1988) considered the meaning of food quality in terms of scientific measurements and contrasted this with practical commercial marketing. Certain factors such as non-adulteration, non-contamination, nutritive and microbiological status are determined by regulating standards. The remaining factors of quality, e.g. perceived quality, are only measurable by sensory panels. Thus research on the composition, storage and processing of foods has little meaning if the effects of experimental conditions on palatability are ignored.

Organic foods are often claimed to be better tasting and fresher. The problem with testing such claims is that they can derive from varietal differences or differences in maturity or ripeness. Several studies have attempted to test whether organic food has better organolyptic qualities.

Schutz and Lorenz (1976 in Beharrel and MacFie, 1991) found labelling vegetables as organic significantly increases acceptance ratings. Appledorf *et al.* (1974 in Beharrel and MacFie, 1991) attempted to determine whether there was a subjective preference for healthy food based on sensory qualities. Colour and odour were important sensory attributes. Hansen (1981 in Beharrel and MacFie, 1991) explained that any comparison of biodynamically and conventionally grown crops is extremely difficult because of the large number of parameters that have to be controlled. His results show a variable connection between the chemical or taste composition of vegetables grown in the two different methods of cultivation. Alvensleben and Meier (1989 in Beharrel and MacFie, 1991) found the appearance of fruit and vegetables was an important factor in consumer perception of quality. In addition, they state that knowledge of production methods and origin is used in consumer choice. Taste tests with identical tomatoes with different labels showed the "halo effect" (Alvensleben and Meier, 1989 in Beharrel and MacFie, 1991). The consumers perceived taste differences based on the labelling alone.

Conventional agriculture normally has higher yields because it reduces limiting stresses on plants, which can then attain their genetic potential. Higher stresses in organic farming may result in smaller products, and thus more concentrated taste, and therefore might be preferred by some consumers. However, other consumers may prefer the potentially more 'dilute' taste of conventional products (Basker, 1992). Preference tests are often used when comparing the taste of organic and conventional products. Some of these studies related to taste were done using humans, and some using animals. Some studies were performed using well-trained panels of tasters in professional conditions while others have been done less formally.

Basker (1992) used tasters who had some experience in taste panel procedures. Overall, he produced 460 assessments of 29 samples covering five fruits and four vegetables. In the end, he found no significant pattern of preference between organic and conventional products. However, after analysis, he discovered that the fruits and vegetables were not all at the same stage of ripeness, which might seriously affect their taste, and thus the results of the experiment.

Woese *et al.* (1997) found, in their review of literature, that results of human sensory studies with trained and untrained tasting panels vary greatly. They also found that, in sensory tests performed with potatoes, differences could be made between varieties but not between cultivation systems (Woese *et al.*, 1997). Similar to the taste results found by Woese *et al.* (1997), a slightly more recent review of literature shows no difference in potatoes, lettuce, green beans, broccoli and spinach. (Kumpulainen, 2001). Evers (1989 in Woese *et al.*, 1997) and Schutz and Lorenz

(1976 in Beharrel and MacFie, 1991) found that organic carrots have lower sensory scores than conventional ones. However, the conditions and characteristics of those studies are unknown to us as the reports were not available, the results have been taken from Kumpulainen's review (2001). Also, Kumpulainen (2001) found that most of the studies showing differences in flavour were studies of leafy vegetables.

In general, there is no trend of better taste in organic fruits or vegetables. In vegetables such as carrots where high water content is preferred organic vegetables may rate lower in preference tests.

Animal Preference Tests

A number of food preference tests have shown that animals are able to discriminate between conventionally and organically grown products. Plochberger *et al.* (1992) investigated the possibility of using laboratory rats for food preference tests as a method for evaluating nutritional quality. Various authors have studied food choice in protein-deficient rats, however, these results have in some cases been contradictory, Halstead and Gallagher (1962 in Plochberger *et al.*, 1992) concluded that rats prefer a complete mixture of amino-acids to one lacking the essential amino acid threonine. Thiamin-deficient rats also chose constantly a food mixture containing B-vitamins. Thus, a rat can select from the available food to meet its needs. Feeding behaviour of healthy rats is not exclusively determined by physiological needs; general features appear to spontaneously influence their food choice. There's evidence that rats prefer sweet mixtures to plain ones, regardless of whether the sweetness stems from sugar or saccharin (Sheffield, 1950 in Plochberger *et al.*, 1992). Another factor influencing food choice in rats is texture: soft or finely divided foods are often preferred to harder and coarser ones (Carlson & Hoelzel, 1949 in Plochberger *et al.*, 1992).

Plochberger *et al.* (1992) conducted a study to determine whether rats can distinguish between products which are equally satisfactory to physiological needs but stem from two different farming systems (biological versus conventional agriculture) and to define the possibilities and limits of preference tests with rats as a method to evaluate nutritional quality. The rats were fed with balanced diet throughout and suffered no deficiency. The investigation was carried out with two groups of rats as test animals. For five generations, one group was fed with biologically grown products, the other with conventionally grown ones. The components of both diets were: oats, barley, toasted soya beans, field peas, carrots, common beets. Every 24 hours the food remnants were weighed to register the consumption and fresh products were offered again. The common beets differed only in the method of production: biological and conventional. They were of the same variety, grown at the same time on the fields of the same soil type and were kept under identical storage conditions. The grain for all test breads was conventionally cultivated, but special ingredients were added to investigate the sensitivity and the perceptive of laboratory rats as well as their basic preferences. Both groups of rats initially preferred wheat to rye. Initially, rats not suffering from any deficiency will choose according to taste and palatability. Any later change in the amount of food ingested is due to physiological needs; the rye bread had a higher content of fat and carbohydrates. The amount of food ingested is determined by energy needs.

The preference tests with common beets demonstrate that biologically grown common beets were significantly preferred (Plochberger *et al.*, 1992). Benett and Henderson (1972 in Plochberger *et al.*, 1992) found that weanlings actively seek and preferentially ingest the diet their mothers ate during the nursing period, even if that diet is relatively unpalatable. This was not the case in this investigation: conventionally fed rats immediately chose ''biological'' beets when offered both types despite the fact that their mothers ate ''conventional'' ones.

Plochberger *et al.* (1992) found the short-term choice of food in rats to be influenced by neophilia, odour, taste, texture and palatability and long-term preference for food to be determined by its physiological effect. If no ill effects are experienced, the rats will mainly ingest the known food. A change in the amount of food ingested reflects physiological needs. This investigation demonstrates that rats are very well suited for food preference tests: they are omnivorous, which allows for a wild range of products, they try each new food offered, they are capable of making a distinction between two products that-according to chemical analysis-both meet their physiological needs and they maintain this choice despite any change of food position. Food preference tests with rats are relevant in the evaluation of food quality. At the same time, long-term studies are necessary to make reliable statements about nutritional quality of products.

From 1987 to 1991, Mäder *et al.* (1993) compared beetroot from bio-dynamic, bio-organic and conventional systems. In the bio-dynamic system, farmyard manure and slurry were used as fertilizers, in bio-organic these organic fertilisers were used with mechanical weed control, and in the conventional system manure, mineral fertilizer, herbicides and hoeing were used. There was also a control plot that did not receive any treatment and a mineral control that received only mineral fertilizer. As part of their experiment, Mäder *et al.* (1993) performed a food preference test using rats. They found that over a five-day feeding period, bio-organic beetroot was largely preferred over bio-dynamic and conventional, while the last two were comparable. In another test over seven days using beetroot juice, they observed the same results, suggesting that texture does not influence the food preference of rats (Mäder *et al.*, 1993).

In their study, Woese *et al.* (1997) reviewed six experiments on taste tests with animals (including the study by Mäder *et al.*, 1993). The animals used were hens, rabbits, mice, and rats, and the studies took place between 1931 and 1993. Out of those six experiments, five showed a clear preference by the animals for organic food over conventional. In a further test (Mäder *et al.*, 1993) used products from three different cultivation systems (organic-biological, biological-dynamic, conventional). When two varieties of feed were compared, rats showed a significantly higher preference for organic-biologically produced feed. The animals did not, however, differentiate between feed from biological-dynamic and conventional agriculture. The reason for this preference is not known. A possible factor may be a different taste or Neudecker's interpretation of "additional compensatory consumption to balance the lower crude protein content in organically fertilised carrots since no effect could be observed on the weight development of the test animals" (Neudecker, 1987 in Woese *et al.*, 1997). However, both organically grown food and conventionally grown food were analysed with chemical analysis and found to meet the physiological needs of the test animals (Plochberger *et al.*, 1992).

Feeding Experiments

Twenty-two authors described feeding experiments with animals in respect of the comparison of the quality of products of plant origin from organic and conventional agriculture or different fertilisation systems. Five different species of animal were used, mainly mammals: rabbits, mice, rats, hens and pigeons. Feeding experiments involve analysing the effect of different diets of the health of test subjects. The fertility of animals often is taken as indicator for unfavourable environmental conditions since it is less strongly genetically determined than other parameters (Woese *et al.*, 1997). In the feeding experiments evaluated, reproduction characteristics were therefore amongst the preferred test criteria. Several studies examined the effects of the test feed on body weight, general health condition and organ weights as well as the feeding behaviour of the animals in the feed selection experiments. In all three feeding experiments with hens there were differences between the test groups. Plochberger (1989 in Woese *et al.*, 1997) could not identify any clear differences between the weight development of chicks. However, significant differences were found egg weight and the distribution of the egg components. (Higher egg weight and higher yolk weight but lower albumen weight when chicks were fed with organic products.) In a series of animal tests, fertility parameters produce results in some cases. A major impairment of fertility through the feeding of products exposed to intensive mineral fertilisation was indicated (Hahn *et al.*, 1971 and Aehnelt and Hahn, 1973 in Woese *et al.*, 1997), in other studies no clear differences could be recognised (Bram, 1974; Alter, 1978 and Meinecke, 1982 in Woese *et al.*, 1997). In three other, extensive studies in rabbits (Gottschewski, 1975; Edelmüller, 1984 and Staiger, 1986 in Woese *et al.*, 1997), the main focus was on mating and rearing results. Contradictory findings were obtained for gestation rate and the size of the litter. In the feed tests with mice (Pfeiffer, 1931; von Grone-Gultzow, 1931; Scott *et al.*, 1960; McSheehy, 1977; Neudecker, 1987 in Woese *et al.*, 1997) and rats (McCarrison, 1926; Scheunert *et al.*, 1934; Scheunert, 1935; Miller and Dema, 1958; Neudecker, 1987; Plochberger *et al.*, 1992; Velimirov *et al.* 1992 and Mader *et al.*, 1993 in Woese *et al.*, 1997), contradictory results were found. The results which have been obtained in more recent feed experiments with mice and rats (Neudecker, 1987 and Velimirov *et al.*, 1992 in Woese *et al.*, 1997) are of special interest in connection with a current evaluation of the situation in the quality of organically and conventionally grown food. No clear differences could be detected in respect of gestation rate and litter weight at the time of birth and weaning and/or the litter size and the birth and weaning weights per young animal. In some cases in litters of animals fed on conventionally produced feed, the share of stillborn young animals and of animals which died shortly after birth was, however, significantly higher.

In summary, the only observed differences in taste detectable by humans, between organic and conventional food, were for carrots and leafy vegetables. However, since we have no details on those studies, it is difficult to tell whether or not the results are reliable and significant. However, it seems that animals are more sensitive at detecting differences between foods from different production systems than we are. In all but one study performed before 1993, animals markedly preferred organic food over conventional food, for some reason remaining unknown.

Nutrients

There are more than 30 studies comparing the nutrient content of organic crops with conventionally produced crops, grown with chemical fertilizers and pesticides. In these studies, various individual nutrients in individual crops were compared. In the more than 300 comparisons performed in these studies, organic crops had a higher nutrient content about 40% of the time, and conventional crops had a higher nutrient content only about 15% of the time. Overall, organic crops had an equal or higher nutrient content about 85% of the time. These results suggest that, on average, organic crops have a higher nutrient content (Worthington, 1998). For two nutrients, vitamin C and protein, there is enough evidence to suggest that organic crops are superior to conventional ones (Worthington, 1998). Compared to crops grown with chemical fertilizers and pesticides, organically grown crops generally have a higher vitamin C content and better protein quality. With respect to desirable ingredients such as minerals, vitamins (B1, B2, C), carbohydrates, proteins and free amino acids as well as organic acids no major differences could be observed between apples, pineapples, strawberries from organic and conventional production (Woese *et al.*, 1997). Further work is needed on other nutrients before any definitive conclusions can be drawn.

PROTEIN

Protein content seems to be affected in some vegetables by the production system. In their review of literature, Woese *et al.* (1997) stated that no trend could be identified for total protein (crude protein), pure protein and relative protein content (% of total protein that consists of pure protein). Total protein, total nitrogen and the total amino acid content tends to be higher in conventionally grown vegetables (Kumpulainen, 2001). This is especially true in nitrophilic vegetables (leaf, roots and tubers). Studies on potatoes and corn have shown the most significant results with respect to protein content. Protein content may be higher in conventionally grown vegetables.

SUGAR, STARCH, ACID AND DRY MATTER

Some other parameters have also been examined in a few studies. These include organic acids, starch, dry matter content and various sugars.

For organic acids and sugars, no clear difference was found by Kumpulainen (2001). Woese *et al.* (1997) also found no differences for both for the proportion of monosaccharides in total sugar and total sugar content itself. In studies on spinach, beetroot, carrots, celery and leeks, no difference was found in organic acids (malic, citric, oxalic, and total acid) (Woese *et al.*, 1997).

Dry matter content seems to differ between production methods for some produce. In general, the dry matter content of above-ground (leaf) vegetables (studies done on spinach, chard, and savoy and white cabbage) was higher in organic crops, whereas no difference was detected in the dry matter and starch content of below-ground (root and tuber) vegetables (Woese *et al.*, 1997). Also, no differences were observed either in dry matter content and sensory properties between organic and conventional fruits in experiments done by Vetter *et al.* (1983 in Woese *et al.*, 1997) and Reinken *et al.* (1990 in Woese *et al.*, 1997). Higher dry matter content in organic products can be explained by the fact that fertilisation is generally less intense in organic agriculture, and therefore organic fruit and vegetables are smaller and thus contain less water. However, this does not explain why dry matter content was only found to be affected by production method in above-ground vegetables.

In a market supply experiment, where potatoes were bought from different stores selling organic and conventional food, it was found that, on a dry weight basis, organic potatoes had a higher glucose and fructose. Conventional potatoes, on the other hand, had a higher content of sucrose (Warman and Harvard, 1998). According to the studies by Naumann et Dettaas (1972 in Woese *et al.*, 1997), Vetter *et al.* (1983 in Woese *et al.*, 1997), Reinken *et al.* (1990 in Woese *et al.*, 1997) and Alvarez *et al.* (1993 in Woese *et al.*, 1997) on apples, pineapples and strawberries, no differences were found in carbohydrates, proteins, free amino acids, and organic acids (Woese *et al.*, 1997).

The content of acids, sugars and dry matter is variable between fruit grown under the same production system. These variables are influenced by microclimate, maturity and other factors, making it difficult to differentiate based on production system alone. There does, however, seem to be a significant difference in dry matter content for some produce, between organic and conventional production.

VITAMINS

There are 27 studies, reviewed by Woese *et al.*, (1997), that examine levels of vitamins in organic and conventionally produced vegetables. The vitamins that were the studied between organic and conventional food are vitamin A, (B-carotene), B1 (thiamine), B2 (riboflavine), C, and E. Kumpulainen (2001) also reviewed literature that compared vitamin contents in organic and conventional production. No difference in vitamin A/B-carotene, thiamine, riboflavine were found if carrots and potatoes in the study by Kumpulainen (2001). Also, no differences in vitamin B content were detected in the 2 studies reviewed by Woese *et al.* (1997).

For vitamin C, about half of the studies performed, found no difference between conventional and organic food. The rest of these studies reported slightly higher contents of vitamin C in organically grown food (Kumpulainen, 2001). The experiments studying vitamin C used potatoes. Potatoes are an important source of vitamin C when consumed regularly, and are a key component of diet in many parts of the world. In most studies, the concentration of vitamin C was either equal (about 50% of the studies) or higher (also about 50% of the studies) in organic potatoes. However, in two older studies (Wacholder and Nehring, 1938, 1940 in Woese *et al.*, 1997), vitamin C was higher in conventional potatoes (Woese *et al.*, 1997). We must however, take into account the major differences in conventional agricultural systems that have occurred since the 1940’s (especially since once again those studies were not available and the results were taken from a review of literature). It seems that potatoes are not the only vegetable whose content of vitamin C is affected by production method. In general, Woese *et al.* (1997) observed strong evidence of higher vitamin C levels in leafy green vegetables. On a more general basis, in another review of literature, Lampkin (1990) noted a higher vitamin C content (28% higher on average) in organic vegetables as well as a higher dry matter content (23% higher) despite the lower yield (24% lower) (Williams *et al.*, 2000). However, in the experiment by Warman and Harvard (1998), no difference was found in vitamin C and E content in sweet corn kernels, between conventional and organic. The levels of vitamins, however, varied greatly from year to year. In fact, vitamin C content of crops is greatly influenced by factors such as ripeness, time of day, post-harvest handling, weather, soil moisture and soil fertility (Warman and Harvard, 1998).

In conclusion, no differences were found in studies examining vitamin A (B-carotene), vitamin B1 and B2. However, there often seems to be a difference in vitamin C (higher in organic), mostly in potatoes and leaf vegetables such as lettuce, savoy cabbage, spinach and chard (leaf beet) (Woese *et al.*, 1997).

MINERALS

Fertilisation method seems to affect mineral and trace element contents of crops, but the effects are not the same for all elements. The compounds that will be examined here are P, K, Ca, Mg, Na, Mn, B, Fe, and Cu.

As part of their study on beetroot, (Mäder *et al.*, 1993) measured the phosphorus, potassium, Ca and Mg of beetroot from each system. They found that phosphorus levels were comparable in all three systems, but 15% lower in the mineral control. Ca and Mg were also similar between the different systems. Potassium, however, was much higher in the conventional system (Mäder *et al.*, 1993). In studies done by Abele (1987 in Woese *et al.*, 1997) and Matthies (1991 in Woese *et al.*, 1997), P and K were higher in organic potatoes than in conventional ones (Woese *et al.*, 1997). The results from these studies are contradictory and details about the experiments by Abele and Matthies are not given. This makes it impossible to draw any conclusions about whether phosphorus and potassium are influenced by cultivation method.

No difference in any mineral or trace element was found from the 8 studies reviewed by Woese *et al.* (1997). The only exception to this is for iron. In some studies, Fe was equal in organic and conventional vegetables, while in others, it was higher in organic. However, most of these studies showed a lack of rigorously controlled conditions, thus, conclusions cannot be drawn from these results (Woese *et al.*, 1997).

Warman and Harvard (1998) compared organic and conventional potatoes and sweet corn, grown on low fertility soil, which had not been fertilised for at least five years, in order to overcome the effects of previous fertilisation. Also, new plots were used each year to overcome the effect of crop rotation. The experiment was done from 1990 to 1992 in Nova Scotia, Canada. They found that in the tubers of organic potatoes, P, Mg, and Na contents were higher and Mn was lower than in conventional tubers. In the leaves, however, B and Fe were higher in organic plants, while Mg, N and Cu were lower. The contents of Fe and Cu in leaves of sweet corn were higher in the conventional system. However, none of the differences found in this study were large (Warman and Harvard, 1998).

Kumpulainen (2001) found conventionally grown potatoes and carrots had higher ash and nitrogen contents, while organically grown ones had higher potassium and sodium contents.

In summary, the minerals or trace elements for which significant (although small) differences were found between different systems are:

- P, Mg, Na (higher in tubers of organic potatoes)
- K, Na (higher in organic potatoes and carrots)
- B, Fe (higher in leaves of organic potatoes)
- Fe, Cu (higher in baby food)
- Mn (lower in tubers of organic potatoes)
- Mn, N, Cu (lower in leaves of organic potatoes)
- Cu, Fe (lower in leaves of organic potatoes and sweet corn)
- Ashes, N (lower in organic potatoes and carrots)

These results, however, come from only two studies, and therefore, must not be used as a generalization.

Contaminants

PESTICIDES

One of the major concerns of people buying organic food is pesticide residues. Fruits and vegetables are the foods that receive the highest doses of pesticides. Jones (1999) found 35% of the food purchased in the United States has detectable pesticide residues, and 1-3% of foods have pesticide levels above the legal tolerance level. In the United Kingdom, 48% of fruits and vegetables had detectable residues (Ministry of Agriculture Fisheries and Food, 2000 in Heaton, 2001). Many of these chemical residues remain on produce after washing and some are taken up by the entire plant and contaminate the entire flesh (Heaton, 2001). There is also variability in the exposure of fruit during application. Apples on the exterior of trees get much higher exposure to pesticides than those on the interior (Heaton, 2001). Cox's apples can be sprayed 16 times with 36 different pesticides under British regulations (Heaton, 2001). Individual apples have been found to contain up to 13 times the average residue levels and carrots can reach 29 times the average (Heaton, 2001). Figures about levels of pesticide contamination are, however, not exact. The methods employed cannot detect all pesticides. In the United States, out of around 600 pesticides in use, only around 200 can be detected by the current available methods (Jones, 1999). It is generally agreed that organic fruits and vegetables contain lower levels or pesticides, however, it is important to determine whether the difference is significant, and if so, what are the impacts on human health.

Despite the above-mentioned statistics, pesticides residue levels authorized in conventional agriculture are very low, most often below the minimal detection limit (Kumpulainen, 2001). Woese *et al.* (1997) and Bitaud (2000 in Heaton, 2001) have reviewed 35 papers with 9100 samples. Pesticide residues were found much less often in organically produced vegetables and fruit.

Many dangerous chemicals that used to be allowed in agriculture are now prohibited. Some of these can travel in the air and remain for a very long time in the environment. These chemicals are just as likely to be present in conventional and organic systems that have been under conventional production previously. Indeed, some pesticides which are now prohibited (DDT, organochlorines) and environmental pollutants such as dioxins, furans, PCB's, and PAH compounds are found equally in organic and conventional fat and oil-containing foods (Kumpulainen, 2001). An American study found detectable levels of DDT in 17% of carrots tested twenty years after this pesticide was banned (Mott and Broad, 1984 in Heaton, 2001). Pesticides can, however, reduce exposure to toxins when used to control mycotoxin contamination (Kumpulainen, 2001).

The amount of pesticides found on fruits and vegetables is lower for organic crops than for conventional ones. However, often the concentrations of pesticide residues are well below the allowable limits (Woese *et al.*, 1997).

HEAVY METALS

High concentrations of heavy metals are another major concern among people who buy organic food. Lead, mercury and cadmium are often measured when considering food quality. The main sources of heavy metals are fertilizers and pesticides. According to Woese *et al.* (1997), there was no clear difference for any of the heavy metals (cadmium, lead, mercury) or environmental pollutants (PCB) studied in any of the reviewed papers, which concerned vegetables and fruit. Lead and mercury do not differ significantly between organic and conventional production because these heavy metals are normally found in very low concentrations in mineral fertilisers. These heavy metals are also not taken up by plants readily. No difference in lead and mercury were detected between organically and conventionally grown potatoes and carrots (Kumpulainen, 2001).

Many studies deal with cadmium. It is present naturally in the environment, and cadmium levels vary greatly between different areas and soil types. The main sources of cadmium contamination are aerial deposition and phosphate fertilizer. Though, another potential source of cadmium is sewage sludge (Woese *et al.*, 1997). Cadmium is present in the soil in varying amounts. Cd uptake by plants depends on soil conditions (soil type and pH) as well as the amount of precipitation during the growing season (Jorhem and Slanina, 2000). In acidic soils, Cd uptake by plants can be significant. Therefore it is very possible to find some cadmium residues in conventional fruit and vegetables. However, conventional products are not the only ones affected. Indeed, some organic farmers are allowed to use slowly-dissolving phosphate, which may or may not contain cadmium. This explains why the results for cadmium in potatoes and carrots in the study by Kumpulainen (2001) were very variable.

Jorhem and Slanina (2000) also studied the cadmium and other heavy metals contents of organic and conventional potatoes and carrots in Uppsala, Sweden. They chose potatoes because they are a major source of Cd and other heavy metals in the Swedish diet, and carrots for their popularity in the Swedish diet as well. They did not find any difference in Cd, Pb, Cr, and Zn between organically and conventionally grown potatoes. The Cr content varied more within the individual systems than between the systems for both potatoes and carrots, and for Zn in potatoes. Pb and Cr in potatoes were at or below the detection limit for all production systems. This study was limited by the small sample size and the length of study. Other studies show contradictory results. This is probably due to the complex factors that influence Cadmium content in crops (Jorhem and Slanina, 2000).

In summary, no significant difference in heavy metal content was found between organic and conventional products for Fe, Pb, Hg, Zn, and Cr. Very often, the levels of these compounds were below the minimal detection limit. Also, results concerning cadmium were insignificant due to the very many environmental factors influencing cadmium contents of plants, such as the amount of Cd in fertilizer, soil conditions and weather.

NITRATES

Forty-one studies reviewed by Woese *et al.* (1997) have addressed the nitrate content in vegetables from different cultivation systems. These studies presents no general findings confirming a lower nitrate content in vegetables from organic cultivation or vegetables grown with organic fertilisers. There are roughly equal number of studies in which no differences in nitrate content were found and the studies in which organically fertilised products had lower levels. In only one of the studies that dealt with nitrate in vegetables was a higher content determined in one organic product (Stan, 1982 in Woese *et al.*, 1997). The review of literature conducted by Heaton (2001) found 14 studies showing lower nitrate content (averaging 50% lower) in organically grown crops and two studies showing insignificant differences. The results of the studies that found minor or more significantly lower nitrate levels for organic produce, can be attributed to the generally lower intensity of fertilisation in organic agriculture, although once again, it is very difficult to set boundaries defining the levels of fertilisation in both cultivation systems. The type of fertilisations also seems to play a role in the nitrate content of some vegetables.

Mineral fertilisers seem to have a larger effect on nitrate content of potatoes than farmyard manure (Woese *et al.*, 1997). Similar results were found in a study by (Warman and Harvard, 1998) where the only difference that could be observed in potato quality between systems using compost and inorganic fertiliser was tissue nitrogen, which was lower in organic potatoes.

In a study of beetroots by Mäder *et al.* (1993) similar nitrate levels were found in 1987 and 1990, but significantly higher levels were found in the conventional plots in 1991. However, the nitrate levels were always found to be below the tolerance level.

Not all vegetables and fruits are affected to the same level by the amount and type of fertiliser. Higher nitrate contents in conventional vegetables were mainly found in leaf, root, and tuber vegetables (Woese *et al.*, 1997). These plants are nitrophilic, meaning that they tend to accumulate nitrogen quite easily compared to fruit, seed and bulb vegetables. These plants have lower nitrate-accumulating potential, and in most studies, have either equal or slightly lower nitrate contents in organically grown plants (Woese *et al.*, 1997). The relative inability of these plants to accumulate nitrogen often leads to technical problems to observe the actual levels of nitrogen. For example, in studies on apples and strawberries, the nitrate were generally very low for both organic and conventional fruits, often even below the detection limit (Woese *et al.*, 1997). One of the important elements effecting the nitrate contents of plants is weather. Leaching and volatilization can reduce the concentration of nitrates in crop fields and increase the contamination of the surrounding environment.

MICROBIOLOGICAL TOXINS

Microbial infections are far more common than toxic substance problems with fruits and vegetable consumption (Williams *et al.*, 2000). They can arise from industrial processing in handling or microbes in soil or animal manures used for growing crops (Williams *et al.*, 2000). Microbiological health hazards are more important than toxicological dangers, and may be more likely to occur in organic than in conventional farming because of the frequent use of organic fertilisers. However, Williams *et al.* (in Williams *et al.*, 2000) state that there is currently no reliable data that can prove organic food is more likely to be contaminated with harmful microbiota.

It has been suggested that organically produced food has higher levels of mycotoxin contamination because organic farming prohibits the use of fungicides. There is no evidence to support this claim (Heaton, 2001). In fact organic farmers would contend that their crops are less prone to fungal diseases because high doses of nitrogen increase the growth rate of crops leading to a thinning of the plant cell walls making the crop more vulnerable to fungal attack (Heaton, 2001).

SECONDARY METABOLITES

Secondary compounds in plants are known as secondary metabolites or phytonutrients. General categories of these compounds are phenolics including flavonoids, terpenes and nitrogen compounds including alkaloids and sulphur compounds. None of these chemicals are known to be essential to human health. They are referred to as phytamins because they play similar roles as vitamins. Though beneficial or neutral in low doses, some of these compounds in high doses may be harmful. These compounds are used in the treatment of human diseases. They can quench free radicals, act as antiproliferative agents, promote detoxifying enzymes, induce differentiation of cancer cells, inhibit metastasis, stimulate the immune system and inhibit tumour blood vessel formation (Heaton, 2001). Some beneficial secondary metabolites include glucosinolates, glycoalkaloids, flavonoids, carotenoids and sulphur compounds (Heaton, 2001).

Secondary metabolites are produced by plants under stress, such as drought, or attacks by pests or pathogens. Pesticide application protects plants from disease and pests and reduces the need for natural plant defences such as secondary metabolites. Therefore, conventionally produced crops, which are grown under low stress conditions, should contain less secondary metabolites. Organic production often uses varieties that are resistant to pathogens. These cultivars naturally contain higher levels of secondary metabolites (Brandt and Mølgaard, 2001). Heaton (2001) found five relevant studies that show higher levels of secondary metabolites in organic vegetables and fruit. Modern diets do not contain enough of these phytamines, thus the consumption of organic vegetable and fruit could promote human health (Brandt and Mølgaard, 2001).

Health Threats

TOXICITY

Toxicity can arise from agrochemical (insecticides, fungicides, herbicides, growth regulators and antibiotics) spray residues or nitrate. However, residues in excess of the acceptable level are found very rarely (Williams *et al.*, 2000). The effect of these chemicals on human health is not well documented. Chemicals such as organophosphtes have been shown to have neurotoxic impacts. A 1997 review of literature (Jamal, 1997 in Heaton, 2001) presented evidence of effects including chronic fatigue, peripheral neuropathy and neurobehavioral system disturbances. Other impacts of chemical pesticides on human health include neurotoxicity, endocrine system disruption, carcinogenicity and immunotoxicity (Heaton, 2001). Pesticides may interact synergistically or antagonistically with each other. Little is know about how cocktails of these chemicals effect human health over the long-term. American researchers discovered that a combination of three pesticides multiplied the toxicity hundreds of times (Abou-Donia *et al.*, 1996 in Heaton, 2001). There are legitimate potential impacts of some synthetic chemical controls on human health. The difficulty is determining the acceptable human intake.

NITRATES

Nitrates in water and in food can potentially endanger health. However, the concentrations of nitrates in fruits and vegetables should not pose a serious risk to human health (Williams *et al.*, 2000). Plants with higher nitrate levels can be produced with both fertilisers and organic manure, but the control of nitrogen supply to the plant with the latter is less precise (Williams *et al.*, 2000). Heaton (2001) discusses how until recently nitrate was considered to be a purely harmful dietary component. It is linked with gastric cancer and infantile methaemoglobinaemia (blue baby syndrome) and may affect DNA alkylation and transcription, teratogenesis (McKnight *et al.*, 1999). High intake of nitrate is a hazard when conditions are favourable for micro-organisms that can reduce nitrate to nitrite. Nitrate is a toxin. It can also, be transformed into nitrosamines in the stomach, which are thought to be carcinogen precursors. There has been recent discussion about some beneficial dietary effects of the intake of nitrates (Heaton, 2001 and Williams *et al.*, 2000). McKnight *et* *al.* (1999) suggest that nitrates can provide host defence against pathogens such as *Campylobacter*, *Shigella* and *Salmonella* and possibly *Helicobacter pylori* and cardiovascular protection due to inhibition of platelet aggregation. There may be beneficial effects of nitrates in some cases, however, the toxicity necessary to defend against gastrointestinal pathogens may also have negative impacts on human health, and the inhibition of platelet formation could be also considered unhealthy for people with blood disorders such as haemophilia.

INFLUENCE ON ANIMAL HEALTH

Mineral imbalances arising from unbalanced or excessive use of chemical fertilisers is a hazard that has long been known to affect the health of farm animals (Williams *et al.*, 2000). In cattle, excessive levels of nitrogen or potassium in soil can lead to hypomagnesia, resulting in grass tetany and poor reproductive performance; phosphorus excess is also associated with copper deficiency (Williams *et al.*, 2000). Fourteen studies have been undertaken over the last 70 years to compare the effect of organic and conventional feed on animal health. In ten of these studies, the organically fed animals fared better (Worthington, 1998). However, few of these controlled intervention studies have compared effects of organic and conventionally grown feeds on animal health in long term (Williams *et al.*, 2000). Scheunert *et al.* (1934 in Williams *et al.*, 2000) observed worse performance in organically fed animals (rats), although Scott (1960 in Williams *et al.*, 2000) showed mice fed on a mixed organic/conventional feed had poorer reproductive performance than those raised either on conventional or organic feed alone. Fifteen studies have found that animals given organic feed fare better than those fed conventional feed. Critics of the earlier studies state that the nutrient compositions of the diets were frequently different between the two test groups. Recent studies have attempted to control nutrient conditions more rigorously (Gottschweski, 1975; Edelmuller, 1984 and Staiger, 1986 in Williams *et al.*, 2000). However, the results of these studies are varied. Some studies found higher pregnancy and birth rates, whereas others found higher numbers of live births for rats fed on organic feed (Williams *et al.*, 2000). The data from controlled animal feeding studies suggests that organic feed may have beneficial effects on animal health. However, there are few studies and the experimental design of these studies has been variable. More research is needed before any firm conclusions can be drawn.

INFLUENCE ON HUMAN HEALTH

There have been no controlled studies that have compared the effects of organic and conventional products in human health (Williams *et al.*, 2000). Such a study would be too difficult to carryout due to costs, ethics and the general feasibility. Such a study would need to be carried out under very carefully controlled conditions over long periods of time. All the factors that could influence human health would have to be kept constant for the test persons in order to be able to identify the effects of different food sources (Woese *et al.*, 1997). This would limit the number and type of subjects who would be eligible and available to participate in such a study. A few experiments from the1930s and 1940s compared the effects of foods produced using either organic or mixed (organic plus chemical) fertilisers. These studies compared the nutritional quality of vegetables and potatoes exposed to different fertilisers. They focused on the effects of the test diet on the general health condition, body weight, proneness to infection, haemogram and the vitamin balance (vitamins A and C) (Woese *et al.*, 1997). No effects were observed in experiments involving 260 adolescents (Wendt, 1943 in Williams *et al.*, 2000) or 300 adults (Reiter, 1938 in Williams *et al.*, 2000). Later studies found that crops grown with mixed fertilisers had more beta-carotene and minerals but lower levels of B vitamins than crops grown organically. However, no effects of these products on blood parameters were observed in adults, although in infants there was a higher daily growth rate and higher serum beta-carotene in children fed on crops grown under mixed fertilisers conditions (Dost and Schupan, 1944 and Schupan, 1972 in Williams *et al.*, 2000). Williams *et al.* (2000) state that due to the lack of relevant dietary data, heterogeneity in the study populations and limited information on growing conditions means, much of this early data cannot be scrutinised according to current scientific criteria. Williams *et al.* (2000) believes that for this reason no valuable inferences or interpretations can be derived from these studies. They also state that there is no reliable data currently to judge whether the levels of antioxidants and related substances are comparable or different in conventional and organic grown foods.

Health impact studies have shown little results because the differences in terms of health effects are not large enough to be readily apparent (Worthington, 1998). If, for example, people stayed well on an organic diet but got violently ill as a result of consuming food grown with chemical fertilisers and pesticides, then the difference would be perfectly obvious. However, there is a more subtle difference. An 8% increase in the incidence of allergies would be much more difficult to detect and would be easy to overlook (Worthington, 1998).

David Leonard states (Diver, 2000) that organic vs conventional food does not play as important of a role in human health than eating habits do. He says that organic agriculture should not restrict itself to claiming its environmentally-friendliness and better nutritional value, but should in addition aim at changing consumers' eating habits. Indeed, 'nutritious' organic food is not necessarily associated with 'healthy eating'. For example, many modern foods are processed and additives are added for many different purposes, and some nutritious parts of the raw food are removed. Some foods are advertised to have less fat, more vitamins, artificial sweeteners, etc. If organic food aims at reducing the amount of all these additives and other processing practices, then maybe there will be a significant difference in food quality compared to conventional food (Diver, 2000). However, this concerns post-harvest processes rather than production methods, and therefore no conclusion can be made from this regarding raw food quality as related to organic or conventional production.

Conclusions: (from Williams *et al.* in Williams *et al.*, 2000)

1. Food is a highly complex medium. In addition to macro and micro-nutrients, typically food items contain small amounts of many components (anutrients) of no nutritional value to consumers. The health benefits and risks of a particular food item depend on the genetic and environmental status of the individual consuming the food and on the ability to absorb (bioavailability) many of the components it contains.
2. There have been very few scientific studies in which foods grown conventionally have been compared, under similar conditions, with those produced organically, in terms of their chemical composition or their biological effects on the consumer organism. Research seems not to demonstrate differences or where differences are detected, they are very small.
3. Some studies have shown slightly enhanced levels of certain micro-nutrients, such as vitamin content, in organic foods compared to foods grown conventionally. In may be ascribed to higher water content in some conventional foods. It is very unlikely that such small nutrient content would have healthy implications for

consumers except possibility for individuals with a particular micro-nutrient deficiency.

4. Anutrients in food come from many sources. The majority of these sources are natural. In raw foods only pesticide and veterinary drug residues may be expected to be higher in conventional foods compared with organic foods.
5. Based on current limited scientific knowledge, it appears that the wildly held public view, that organic foods are safer and healthier than conventional foods, is incorrect for the great majority of consumers.

In short, there is some evidence that organic fruits and vegetables may be healthier. This evidence seems to be sufficient to convince the people who strongly believe in organic food from a 'food quality and health' point of view that organic food really is better for you.

Conclusions

Few studies compared organic and conventional crops under the same conditions. The studies that have, show small differences in nutrients. Studies such as those reviewed by Woese *et al.* (1997) and Worthington (1998), show fresh organic products to have a higher concentration of some nutrients, however, the limitations of these studies must be considered. The observations do not apply to all nutrients and all crops, and some of the reported differences can be explained by higher water content of conventional products (Williams *et al.*, 2000). According to Heaton (2001) the only parameters for which available data was sufficient to draw conclusions, about differences between organic and conventional production systems, were vitamin C, nitrates and pesticide residues.

Taste tests with animals, unlike with humans, provided significant evidence that organic food is preferred over conventional food. However, the reasons for this preference need to be determined before these results can be used to support organic production and consumption.

Pesticide residues in most foods are very low, often below the minimal detection limit. This makes it very difficult to determine whether the levels are actually lower in organic food, as would be expected. Thus pesticides could be considered a minor threat to health, as shown in the study by Williams *et al.* (2000), where in almost all samples, the levels of pesticides were well below the threshold for adverse effects on health. However, the procedure for setting allowable limits for pesticide intake is rather arbitrary. Little research can be conducted on human test subjects and any such studies do not usually address the long-term health effects (Heaton, 2001). Therefore, limits are set by extrapolating from results of research on animal test subjects. Without a better understanding of the effects of pesticides on human health, the impact of eating conventional versus organic produce can not be determined.

Some researchers are unconcerned with pesticide residues. They state that toxicity from synthetic pesticides is much lower than toxicity from natural components of food (Kiraly, 1996 and Ames *et al.*, 1990). In fact, when small amounts of mutagenic and carcinogenic pesticides (both natural and synthetic) are consumed, they are neutralised by antioxidants in our body (Kiraly, 1996). Others show a greater concern. Heaton (2001) states that "given the current evidence, the continuing doubts over the levels of pesticides in and on non-organically grown food and the potential synergistic effects of multiple residues…a precautionary approach [is recommended]".

The level of contamination from some toxic compounds (environmental pollutants such as heavy metals) did not seem to be affected by the production system. In fact, organic food is perhaps just as susceptible to airborne pollutants as conventional food. Buffer strips between roadways and urban areas required by certified organic production are often minimal and contamination from dry deposition or precipitation cannot be prevented by organic standards. The levels of heavy metal contaminants should, therefore, be similar in both systems (Williams *et al.* 2000).

Finally, some people still claim to 'feel healthier' when eating organic food. Most people have a lack of reliable information about organic products, the information provided to them comes mostly from organic food producers or retailers. Consumers perceive and believe that organic food as healthier. This may lead to a "placebo effect" (Williams *et al.* 2000), people may be healthier because they feel better about what they eat.

6. Survey

Introduction

Defining food quality, as previously mentioned is very difficult. If asked, people often use words and phrases which describe their own, personal beliefs and opinions. The textbook definition itself keeps changing over time and new elements are constantly being added. The aim of this survey was to collect people's definitions of food quality and to see how many people actually buy organic food and for what reasons. We were particularly interested in knowing whether the purchase of organic food was in any way related to some of the characteristics defining food quality.

CONSUMERS

Some researchers have attempted to discover the reasons why people buy organic food. The results of several studies conducted in the United States are summarised below.

Income:

Studies in the U.S. generally suggest that higher income households are more likely to purchase organic products, however, there also seem to be some exceptions (Thompson, 1998). Willingness to pay for pesticide-free produce declined in higher-income groups. In Tucson, Arizona, propensity to shop at the natural foods supermarket rose with income, yet higher price differences between organic and conventional produce reduced the likelihood of choosing organics at the natural foods supermarket but not at the food co-operative. Jointly, these study results seem to suggest that despite high price premiums for organic foods, higher household incomes do not necessarily indicate higher likelihood of organic food purchases. Some consumer segments with lower incomes are more frequent buyers of organic products and tend to have shopped for organic products at retail outlets other than mainstream supermarkets.

Age:

The Hartman Group found that the consumer segment with the highest propensity to buy organics, contained a higher-than-average proportion of people forty years and over (Thompson, 1998). Another segment very interested in purchasing organic but with less disposable income, displayed a higher-than-average proportion of consumers under 35 years (Thompson, 1998). The *Fresh Trends* survey tends to corroborate these differences in purchases by age: the highest percentage having bought organic produce were found in the 18-29 and 40-49 age brackets, whereas the age group least likely to buy is the over 60 bracket (Thompson, 1998). However, these surveys did not test the significance of the results.

Gender:

National surveys of the population of the United States suggest only small differences in purchase behaviour corresponding to gender. The Hartman Group does characterise one segment with potential for purchasing organics as having a higher-than-average presence of female heads of the household (Thompson, 1998). The limited evidence suggests that gender contributes little to explaining differences in organic purchase behaviour, although gender and marital status together might be important in identifying some organic consumers (Thompson, 1998).

Marital Status:

The Hartman Group distinguishes the two population segments that purchase more organic food by marital status. The over 40 segment displays a high percentage of divorces, whereas the below 35 has a higher proportion of never married persons (Thompson, 1998). In contrast, The Food Marketing Institute's group is the group with the highest percentage of respondents willing to pay more for organic foods had a higher percentage of married people (66%) than in the total population (60%) (Thompson, 1998). Only one of the other study has employed information on marital status. Groff *et al.* (1993 in Thompson, 1998) found marital status to be statistically insignificant.

Education:

The levels of educational attained in relation to organic purchasing behaviour have been measured. The national evidence suggests positive correlation between education and organic purchases. The Hartman Group and The Food Marketing Institute segments contain higher than average percentage of college graduates. In Alaskan direct markets, buyers of organic produce tended to be more educated. However, in California there was no statistical difference in education levels between buyers and non buyers of organic produce. The frequency of organic purchases was not associated statistically with educational levels among co-operative patrons in New York (Thompson, 1998). College education increases the likelihood of being willing to pay more for pesticide free produce according to Misra, Huang and Otto (1991 in Thompson, 1998). However, other studies have found that when graduate study is distinguished from undergraduate study, higher educational attainment lowers the probability of choosing organic products (Thompson and Kidwell, 1998) or of considering organic produce better (Byrne *et al.*, 1991 and Groff *et al.*, 1993 in Thompson, 1998. These conflicting results regarding the effects of educational attainment on organic purchase behaviour suggest that different levels of education alone may not be a predictor of consumer purchasing behaviour. It is unlikely that surveys that generalise education in to groups as large as college education can capture the changes in consumer preference with respect to food quality.

Household Size:

In organic consumer purchasing surveys household size, and more specifically, the presence and age of children is one of the least investigated demographic characteristics. The only national survey explicitly including presence of children is *Fresh Trends* (Thompson, 1998). Differences in purchase of organic produce vary only slightly given the presence of children 18 or under. Household size did not differ among purchasers of organics in Alaska and the presence of children had no statistically significant effects in studies in Delware, however, willingness to buy organic produce even if it had sensory defects, did increase with the household size in Georgia (Thompson, 1998). Thompson and Kidwell found that the probability of choosing organic produce increased with the number of children in the household (Thompson, 1998).

Although a quarter of U.S. consumers apparently have purchased organic foods (Thompson, 1998), the organic market share at retail remains quite small. Attitudes, motives and willingness to pay for organic products have been measured, but no retail data have been made available. Demographic variables, such as age, marital status, number and age of children, and educational level attained might be important variables in explaining and predicting consumer demand for organic products. Estimates of habit and persistence when purchasing organic food may be linked to age and household composition might also be important for measuring the potential growth of organic foods.

CONSUMER ATTITUDES

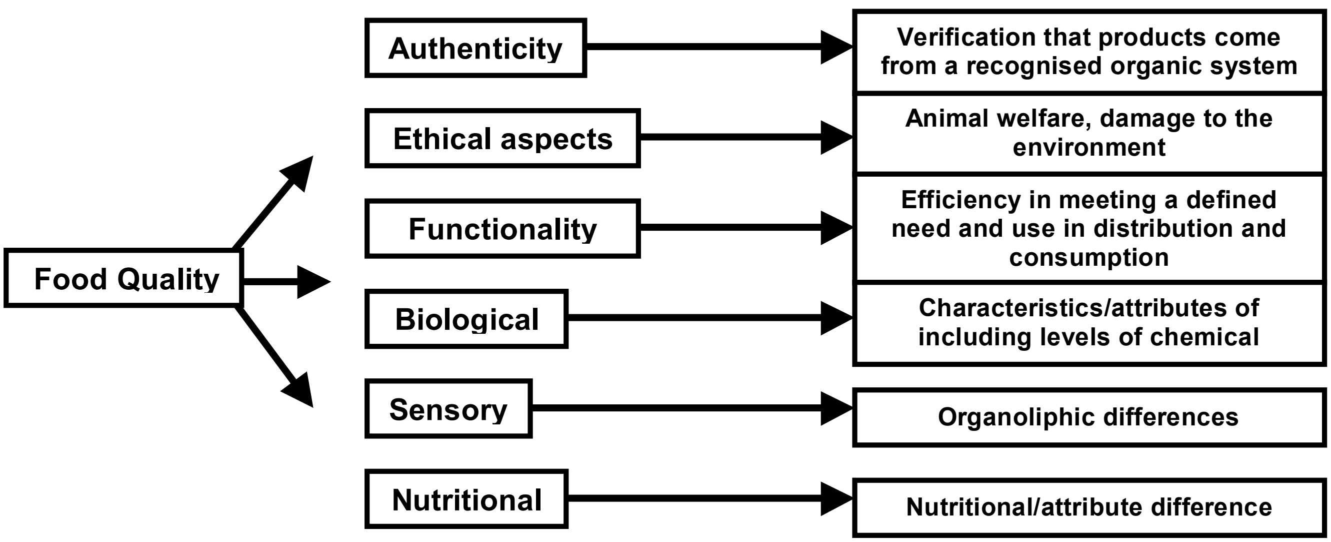
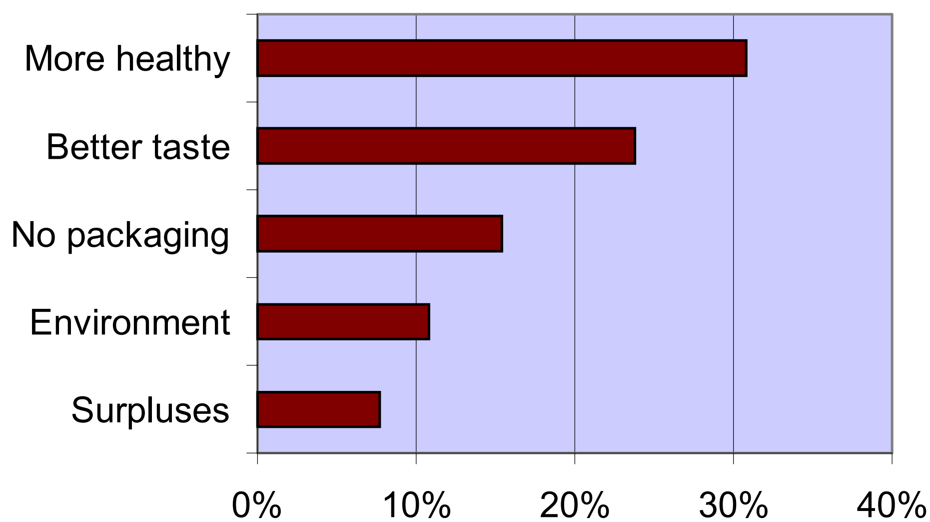


Figure 1. The conceptual framework of organic farming food product quality and acceptability. (Beharrell and MacFie, 1991)

In the UK, Stopes and Woodward (1988 in Beharrell and MacFie, 1991), found that a minority of the population, 4 %, have not heard of organic farming. They also found that substantial number of the British believe chemical sprays are increasingly appearing as residues in the food we eat (65 %) and that the countryside and the environment are being destroyed by modern farming methods (60 %). Survey results from Elm Farm Research (1988 in Beharrell and MacFie, 1991) show that organic foods are overwhelmingly purchased for dietary benefits (96 %).

The study performed by Dixon and Holme (1987 in Beharrell and MacFie, 1991) supports the assertion that the people in the UK are overwhelmingly concerned with health and nutrition rather than with the environmental factors. This suggests



that consumers are more concerned with their own health and welfare than that of the natural ecosystem.

Figure 2. Reasons for purchasing organic food in the United Kingdom. (Dixon and Holmes, 1987 in Beharrell and MacFie, 1991)

A study conducted in the USA (Jolly *et al.*, 1989 in Beharrell and MacFie, 1991) analysed various attributes concerned with organic foods. Jolly *et al.* (1989 in Beharrell and MacFie, 1991) found that all the key factors: nutrition, health, environment and safety, rank equally. The level of concern over residues was found to be high compared with dietary risk factors usually ascribed to fat and cholesterol intake-a major case of heart disease.

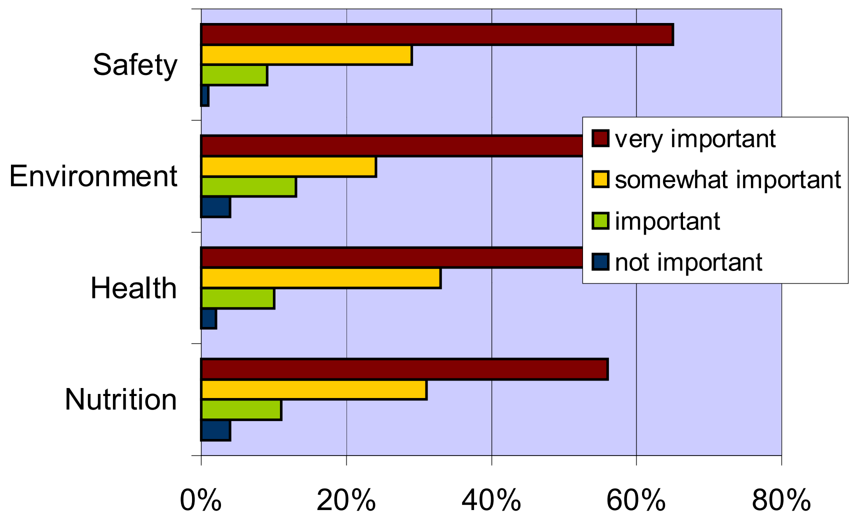


Figure 3. Consumers perceptions of the benefits of eating organic food in the United States. (Jolly *et al.*, 1989 in Beharrell and MacFie, 1991)

In an article about consumer attitudes, Ekelurd (1989 in Beharrell and MacFie, 1991) found consumer preferences to be connected with the complex question of food quality. In Sweden, as in the UK, the increasing demand for organic produce is strongly linked with freedom from chemical residues and personal health rather than environment issues. This relates to food quality because less chemical residues on food will increase food quality.

Consumer attitudes in Germany show some variation from the British pattern, with a greater emphasis on environmental linkages; broader political and ecological factors bear strongly on the demand for organic food (35%) in contrast to quality or related factors (16%) (Beharrell and MacFie, 1991).

The relationship between food quality and organic farming is difficult to analyse and evaluate (Beharrell and MacFie, 1991). The problem is that some consumers are calling for agricultural products to revert to organic methods and for food processors to abstain from adding chemicals to our food supply because they feel these chemicals are polluting the environment and constituting a threat to human health (Maga, 1983 in Beharrell and MacFie, 1991). They firmly believe that organically grown food tastes better, is better nutritionally and is safer for health than conventionally grown processed and marketed food. Because of these beliefs, they are willing to pay a premium for organically grown foodstuffs regardless of whether these beliefs are validated by research.

Methods

The respondents came from different countries, mainly Canada, Denmark and Poland, but some responses were given by international students studying at KVL (The Royal Veterinary and Agricultural University, Copenhagen). The majority of people surveyed were university students between the ages of 18 and 30 years.

The survey consisted of five questions. The first was a yes/no question. The second was a multiple choice. The last three questions were open ended. The multiple choice question provides responses for why the surveyed bought organic food. The purpose of having the open ended questions was to allow respondents to define, in their own words, what they meant by food quality. The questionnaires were distributed either via the internet (Montreal, Vancouver, Warsaw) or directly to the respondent, in the form of a paper questionnaire (Copenhagen, Warsaw).

Questionnaire:

1. Do you buy food certified as “organic”, “ecological”, “biological”?
2. Why do you buy vegetables and fruits certified as “organic”, “ecological”, “biological”?
   (you can tick more then one answer)
   - environmental concern
   - fashionable / trendy
   - healthier
   - cheaper
   - more available than conventional
   - taste better
   - look better
   - produced or marketed locally
   - coincidence
3. Answer this question if you ticked “healthier” in previous question.
   What do you mean by “healthier”?

4. If you used the term “more nutritious” in previous question, what do you mean?
5. What does the term “food quality” mean to you?

Quantitative results were compiled directly into an excel spreadsheet. The qualitative results were read and classified into response categories. These categories were used to make quantitative results of the qualitative data. All data was combined in a final spreadsheet for data analysis (see appendix 1).

Results

We received 73 responses to surveys from Warsaw, 28 from Copenhagen, 17 from Vancouver, 11 from Montreal and 9 from KVL international students. Not all respondents answered questions three and four, the questions about health and nutrition. Thirty six from Warsaw, 15 from Denmark, 14 from Vancouver, 9 from Montreal and 4 from the KVL international students did respond to these questions. Question five, the definition of food quality, was answered by all respondents, regardless of whether they purchased organic food.

Table 2. Responses to questions 1 and 2 of the survey, classified by city.

	Warsaw (73)	Denmark (28)	Vancouver (17)	Montreal (11)	International (9)
Purchase Organic Food	43	21	14	10	9
Environmental Concern	12	20	14	6	7
Fashionable/Trendy	2	1	0	0	0
Healthier	33	17	14	9	4
Cheaper	1	1	0	1	2
More Available	0	2	0	1	2
Better Taste	16	7	7	3	3
Better Appearance	6	2	0	1	1
Produced/Marketed Locally	3	7	10	5	4
Coincidence	9	5	2	3	3
Others	0	4	0	0	0

Most people surveyed purchased organic food, however, in Warsaw only 60% of respondents gave an affirmative answer for the first question. The most common reason for purchasing organic food was environmental concern in Denmark, Vancouver and amongst international students, and in Warsaw and Montreal it was health. The second most common response was environmental concern in Warsaw and Montreal and health in the other respondent groups. Local marketing and production and taste were the third most common responses for all survey groups.

Almost all responses to the question about the term "healthier" are associated with toxicity of chemical contaminants. Most answers mention pesticide residues. When explaining what they meant by "healthier" several surveys from Warsaw mention more nutrients. When explaining what is meant by "more nutritious" some surveys from Warsaw referred to more vitamins. The rest of the groups gave other varied responses.

The last question of the survey, the definition of food quality, yielded varied responses. The general responses included sensory and food safety terminology. In Warsaw responses mentioned nutrients. Some of these responses stated that food had to meet legislated food standards. Several Polish surveys stated that food quality is the meeting of consumer demands. Environmental concerns, animal welfare concerns and local production were only mention by a small number of respondents in their definitions of food quality.

Discussion

This survey has limited potential for data interpretation and comparisons between cities, as the survey samples are very low. Therefore any results discussed cannot be considered significant or representative.

The affirmative answer for the first question of the survey does not necessarily mean that the respondent purchased organic food regularly. Many people surveyed only purchase organic food from time to time. Most respondents stated that they purchased organic food, however, there were less affirmative responses in Poland. This is perhaps due to the small size of the organic market, as well as the low awareness of organic production. Organic food is much more expensive than conventional food and Polish people have little disposable income to spend on luxury/accessory food. Polish people spend 29% of their monthly income on food

(GUS, 1999) in comparison with the average of less than 10% in Western European countries. This is especially true for Polish students, who have even lower incomes. The consumer perception of organic food in Poland, is that the price exceeds the product quality. This means that Polish consumers are not predisposed to purchasing organic food.

Organic farming is usually associated with environmental safety. Our results show the same trend, except for in Warsaw where less than a quarter of the respondents said that they buy organic food because of concern for the environment. This may be due to the fact that until recently, Polish agriculture, was less intensive than agriculture in Western Europe and North America. Polish agriculture used less fertilisers and pesticides and therefore, had less impact on the environment. It is reasonable to state that Polish consumers are not that concerned with environmental issues. Polish agriculture is, however, currently developing and environmental problems may arise and a greater environmental awareness may develop in the near future. Students in Warsaw seemed to attribute more importance to the health aspects of organic food that other student groups. This is probably due to the focus of the organic movement on health concerns in Poland, rather than environmental concerns as in the rest of the world. The health concerns, specifically toxicity, are more publicised in Poland. Local marketing and production was of relative importance to all groups surveyed. In Poland there may be a particular concern with the safety of imported food.

In response to the question about health, respondents seemed most concerned about toxicity. This was generally associated with pesticide residues. Probably, the respondents refer to pesticide use because it is the most prominent distinguishing feature between organic and conventional production. People seem to believe that pesticide residues pose a potential threat to human health. One third of responses from Warsaw mention less chemical fertilisers. These people may be referring to nitrate contamination. A few people in Warsaw mentioned heavy metals specifically. It is possible that these responses talk about heavy metals because they see this as a distinguishing feature between organic and conventional production. Nineteen people out of the total surveyed, half of those who referred to toxicity, stated that there are no pesticide residues in organic food. This is not the case as produce is contaminated from persistent agrochemical pollution in soil, from synthetic chemical applications in neighbouring fields or natural pesticides on crop plants. This suggests that people have inaccurate perceptions about the level of contamination in organic produce. Nine people in Warsaw, six in Vancouver and two people in Copenhagen referred to higher levels of nutrients. Ten of these people specified vitamins and five minerals. These people seem to believe that vitamins and minerals are the most important components of health in produce or that these components are most affected by the production method. Five people mentioned that organic food is more healthy because it does not contain genetically modified food. This shows insecurities with GMO technology. These respondents seemed particularly concerned with long term health effects of consuming GMOs. A few people mentioned that they feel morally healthier when they buy organic products because they know that these products are socially or environmentally better. Four people simply stated that organic food is healthier for the environment alone.

The definitions of food quality were varied. All responses discuss food properties because these properties are related to quality. More than half of respondents mentioned some sensory terminology. The most frequently used terms were taste and appearance. Texture and aroma were also mentioned. All of these sensory characteristics are interrelated and are associated with other quality parameters.

One of the components of food quality is health. The component parts of health are food safety and nutritional value. Safety refers to potential damages to the body and nutritional value is related to the maintenance of human physiology. Nearly half of all respondents mentioned food safety. This is an important characteristic of food quality when considering the difference between organic and conventional production. Chemical toxicity, additives and microbiological contamination were all responses that related to the general category of food safety. Nearly one third of the respondents mentioned nutritional value. These responses referred specifically to vitamins and minerals. This may be due to their specific concern for vitamin and mineral intake or they may be using the term nutrients to refer to nutrients other than vitamins and minerals.

The references to meeting consumer demand, made by some respondents in the Polish surveys, reflect the textbook definition of food quality. Other respondents stated that food quality is realised when food meets legislated standards. This may be due to the historical importance placed producing quantity rather than quality food in Poland. In order to control food quality the government enforced national food standards. The historical definition of food quality was, therefore, simply meeting these food standards. Many of the polish responses match several of the published definitions of food quality. This is likely due to the high proportion of responses from the Faculty of Human Nutrition and Consumer Sciences. These students are more likely to have an understanding of the term food quality.

Other responses to the definition of food quality included storage, labelling, packaging. These components relate to the post harvest conditions of products and therefore the final sensory and nutritional quality of the produce. Time of storage, packaging and the cooking characteristics also refer to the convenience and functionality of food. The functionality and convenience are becoming a larger issue in marketing of food and meeting of consumer demands. Product differentiation is necessary to develop a consumer niche. This is becoming more important for the farmer or marketer because of declining food prices and revenues.

New characteristics that contribute to the term food quality are biological value, ethics and authenticity (Rembiałkowska E., 2000, Diver S. 2000). Five respondents refer to natural food. This is related to product authenticity. Eight respondents spoke about environmental concerns and four respondents mentioned local production and marketing, six respondents referred to animal welfare and two people mentioned GMOs. This could be interpreted as a health or environmental concern. All of these responses could be attributed to the ethical properties of food. One response mentioned “energy” this could be a reference to a holistic quality included in the category biological value.

In general the definitions tended to focus on one component of the modern food quality definition. Some people had very weak understanding of the word food quality or had difficulty defining this term in the context of our survey. There was some correlation between the reasons stated for purchasing organic food and the ability of the respondent to define food quality.

Conclusions

The survey shows that all components of food quality are of concern to our respondents. In general, health and ethical concerns are the main reasons for purchasing organic foods for our sample group. This suggests that the discussion of the difference in food quality is very relevant to consumers. Many consumers perceive a difference between organic and conventional food with respect to health parameters. These consumers may have been mislead by marketing or media about the extent of differences between the food from the two production systems. Other components such as ethical values are, which differentiate between organic and conventional production, also becoming important aspects of food quality.

7. Experiment

Introduction

Several parameters of food quality were analysed for organic and conventionally produced Golden Delicious apples. Dry matter, firmness, sugar, acid content and pH were used to determine the internal quality of the fruit and volume and colour to evaluate the external appearance. Near infrared spectral analysis was performed to see how well spectra correlate with other internal fruit quality parameters and to determine how well apples can be classified by production method using NIR technology. Many studies have attempted to determine whether it is possible to determine the internal quality of apples using non-destructive NIR spectroscopy (Peirs *et al.*, 2000). Soluble solids content (SSC) is a common characteristic used for assessing apple fruit quality (Ventura *et al.*, 1998).

Reganald *et al.* (2001) found that organic Golden Delicious apples were more firm or as firm as conventionally produced apples at harvest and after storage. They also found the ratio of soluble solids (sugar) content to acidity (tartness), an indication of sweetness, to be most often highest in organic fruit. Reganald *et al.* (2001) confirmed their data by conducting taste tests with untrained sensory panels. The taste tests found the organic apples to be sweeter after six months of storage than conventional apples and less tart at harvest and after six months storage than conventional apples. The same taste tests, however, could not discern any difference in firmness among apples at harvest or after storage. Taste tests also found no differences among organic and conventional apples in texture or overall acceptance.

Weibel *et al.* (2000) found that organic apples had significantly firmer flesh that conventionally grown apples. They also found organic apples had better taste. This study also showed higher levels of phosphorus, phenols, and nutritional fibres. This allowed for 100% accurate classification of the apples using a picture producing method.

This experiment will test the differences between organic and conventional apples for several quality parameters. The causes of variation in apples for the tested parameters will be analysed. And the potential for classification of apples using near infrared technology will also be tested.

Methods

This experiment was carried out over four days. The apples were purchase on the first day of the experiment. Spectra and colour readings were taken on the second day of the experiment. The firmness, volume and juicing and chemical analysis were taken over second, third and the first half of the fourth day. Apples were processed consecutively from conventional to organic.

APPLES

The "økologisk" apples came from Italy. The apples were class one apples. They were packaged in plastic bags with ventilation holes on the 18th of April, 2002. The price of the apples was 4,16 DKK per apple. The conventional apples came from Gardonne, France. They were also class one apples. They were packaged loose in boxes on the 20th of March, 2002. The price of these apples was 2,95 DKK per apple. The harvest date and the post harvest storage conditions of neither the organic or conventional apples were known. The apples seemed, however, to be at a similar stage of maturity. This experiment is a market-oriented supply study. Therefore, very little information about the pre-market conditions of the produce is available. Fruits were stored in the lab room for 24 hours for equilibration before the experiment. Each apple was labelled with a number representing the order of processing and the cultivation method, e.g. C44 or Ø101.

In order to compare organic and conventional apples measurements of the NIR spectra, colour, volume, firmness, dry matter, sugar content and acid content were taken.

NIR SPECTROSCOPY

Many researchers in the 1980s used NIR to measure sugar content in fruits and vegetables such as onions, peaches, apples and melons. These researchers used a rotating monochromator. This method of obtaining NIR spectra can take minutes. Bellon-Maurel (1992, in Abu-Khalaf, 2002) developed a faster NIR spectrometer. This system uses fibre optics and a charge couple device camera instead of a photon multiplier detector to measure the returning light signals. Spectral measurements using this spectrometer take seconds to complete. Various studies have effectively used NIR spectroscopy to measure soluble solids (sugar), acid, dry matter and firmness in apples (Abu-Khalaf, 2002).

Near infra red technology can be used to measure the unique spectral signature of fruit and vegetables (Schaare and Fraser, 2000). This spectral signature can be used to determine the internal quality as the NIR signature will register sugar levels and potentially other quality parameters (Abu-Khalaf, 2002). Herschel recognized NIR energy, the energy region between 780 and 1100 nanometers (nm), at the beginning of the nineteenth century. To use the near infra red spectrum for analytical purposes, first necessitated the development of a sensitive detector and computers with adequate capacity for mathematics. Since the 1960s NIR spectral analysis has been used to identify crop varieties and to measure moisture, protein, fat and meat tenderness and to measure the internal qualities: firmness, acidity and soluble solids content of fruits (Abu-Khalaf, 2002).

The reasons for using of NIR technique as a form of analysis are (Shadow, 1997 in Abu-Khalaf, 2002):

1. NIR measurements are extremely fast
2. NIR instruments are easy to operate
3. There is little or no sample preparation required
4. NIR technique is safe, environmental friendly
5. NIR technique is inexpensive
6. NIR is ideal for complex matrices, such as food

When light is directed towards an opaque object some light is absorbed and the remainder is reflected. This diffused reflected light can be used to measure the amount absorbed. NIR spectroscopy detects the organic molecules in food. Compounds containing organic bonds such as C-H, C-O-H and C-N-H interact with the NIR portion of the spectrum (800-2500nm) (Osborne, 1981). NIR spectroscopy detects vibrations of organic molecules in the reflected light. These vibrations are overtones of the IR absorption bands of chemical groups. Overtones are easily detected when the band causing the fundamental vibration is a bond between two unlikely atoms such as carbon and oxygen. The NIR range is the only electromagnetic spectrum that this particular measurable interaction occurs in. NIR light is energetic enough to bring atoms within a molecule in vibration relative to each other. These interactions occur at the speed of light. This interaction returns a unique light signal that can be recorded as a graph of wavelength versus reflectance intensity. This graph shows peaks and troughs at different light wavelengths representing the presence and concentration of organic chemicals in the analysed substance. The NIR spectra contain about the harmonic and combination bands of organic functional group vibrations. These absorption bands are often overlapped. This means that chemomoetric methods are required for data processing.

Multiple regression techniques coupled with different data treatments yield high correlation for a number of analytical parameters (Osborne, 1981). However, the change in reflectance caused by a significant change in composition very small. Sensitive reflectance measurements are required to measure differences in composition. Ideally, reflectance measurements should be made on homogeneous samples (Osborne, 1981). Whole apples may not be homogenous this increases the error and may decrease the correlation of variables. Whole fruit can have variable sugar contents for example as found by Martinsen and Schaare (1998) with kiwifruit.

The apples used in this experiment were purchased on the 22nd of April 2002 at the OBS grocery store in the City 2 mall in Tåstrup. Approximately one hundred organic and conventional golden delicious apples were purchased.

NIR spectroscopy was used to collect spectra of both organic and conventional apples.

The equipment that was used in the experiment is an OEM (Original Equipment Manufacture) device. It is tec5 company multi operating spectrometer system.

The spectrometer system consists of two parts (see Fig. 5):

1. Light source; and
2. Spectrometer optical components.

The spectrometer optical system is based on:

1. A Zeiss monolithic miniature spectrometer (MMS 1) NIR enhanced, which consists of a body made of UBK 7 glass with aberration corrected grating. The Zeiss MMS 1 NIR enhanced is the sensor. The detection range of this sensor is 306-1132 nm.
2. A fibre cross section converter (circular light shape to line shape) as optical entrance.

Figure 4. Spectra measurements.

3. A Hamamatsu (S4781, 256 pixels) photo diode array (PDA) as a detector. Order sorting filters are applied during manufacture to different regions of the array to eliminate detection of second order spectra over this wide wavelength range (306-1132 nm). A 15-bit analogue to digital conversion device was used, under the control of tec5 software.

Both of fibre cross section converter and PDA are fixed to the glass body of MMS 1 NIR enhanced Zeiss sensor (Fig. 4).

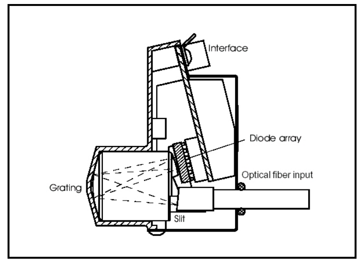


Figure 5. Zeiss MMS 1 NIR enhanced sensor module (Zeiss company, 1999 in Abu-Khalaf, 2002).

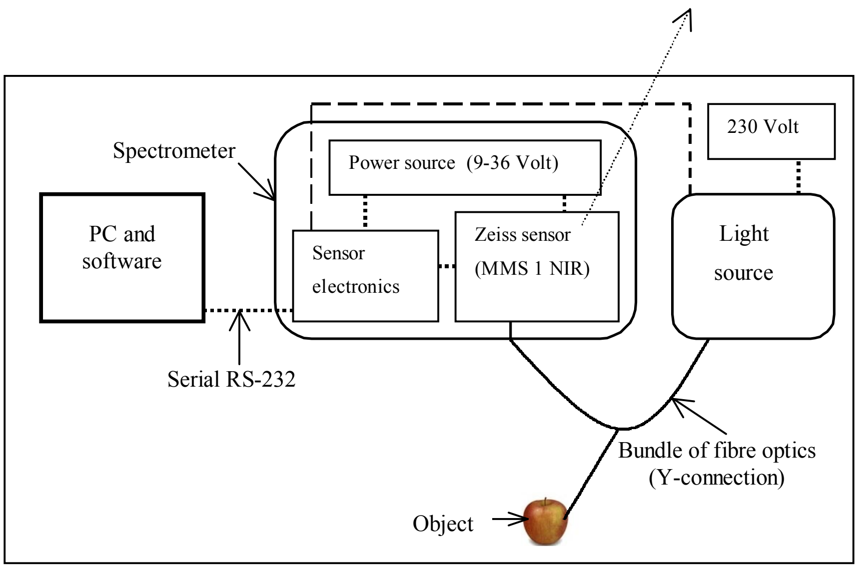


Figure 6. The tec5 spectrometer system (Abu-Khalaf, 2002).

A scanning Zeiss MMS1 NIR enhanced spectrometer was used to collect reflectance readings over a wavelength range of 700-1100 nm in 2 nm increments, yielding 200 values per spectrum. . A plate made of $BaSO_4$ was used as a reference spectrum. The light source consisted of 12V/100W tungsten halogen lamp. The light passes through a bundle of optical fibres to the fruit, and reflected light is transferred to a photo diode array (PDA) detector through another fibre optic bundle. A holder was designed to support fruits and to direct the light in a 45º angle to fruits (to avoid specular reflectance, total reflection and no absorbtion), and to maintain a distance of 1 cm between the probe and the apple. The spectrometer has a very good stability of light versus time and temperature (less than 6.43% variation).

Measurements were taken without removing the skin. This conforms with the recommendation made by Lammartyn *et al.* (2000 in Abu-Khalaf, 2002) who recommend that products should be analysed in the manner in which they are most often consumed. The skin does not interfere with the spectral reading as the penetration of the light is around 5mm into the interior of the fruit. Therefore, the information received from the tissue of the fruit greatly outweighs the information from the skin alone. The apples were measured three times on arbitrary sides of the apple. These three measurements were averaged to arrive and the final spectrum data used in the analysis.

VARIABLES

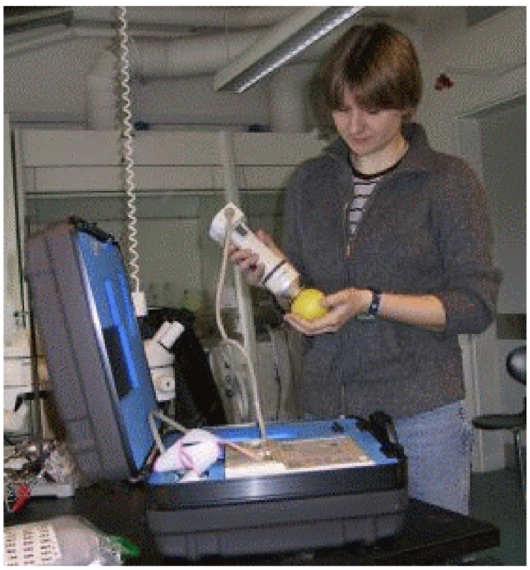


Figure 7. Colour measurements.

Colour:

Measurements of the colour hue, chroma and saturation of the apples were taken using a Precise Colour Communication Minolta (CR-300). Two measurements were taken for each apple. These measurements were taken on two arbitrary regions of the apple or in different colouration regions of the apple if the colouration was not uniform. The two measurements were averaged to arrive at the final colour data used in the data analysis.

Figure 8. Volume measurements.

Volume:

The volume of the apples was measured using water displacement. Apples were immersed in a known volume of water and the remaining volume of water was measured using a graduated cylinder. The volume of water displaced could then be calculated from the initial volume of water minus the remaining volume. This gave a crude but quick measurement of the volume of the apple.

Figure 9. Firmness measurements.

Firmness:

Measurements of firmness were taken with a Bosch penetrometer (model FT 327). A small slice was removed on two arbitrary sides of the apple to expose the interior. Pentrometer readings were taken in the unit kg/cm^2.

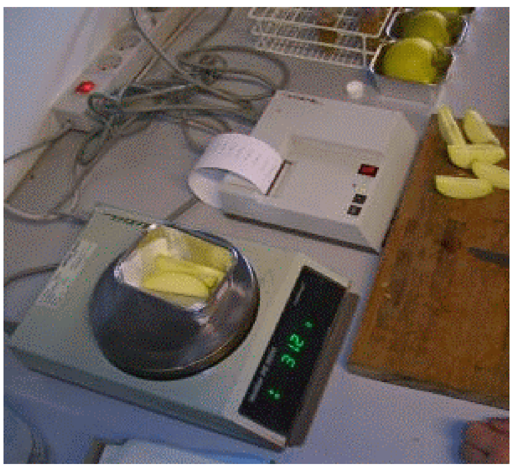


Figure 10. Dry matter measurements.

Dry Matter:

One quarter of the apple was used for determining the dry matter content. The apple was divided into eight pieces and the core was removed. Two arbitrary pieces were chosen on opposite sides of the apple. The mass of these samples was then taken and the samples were dried for four days in a kiln at approximately 70°C and then the mass was taken again.

Figure 11. Juicing.

Juicing:

The remaining three-quarters of the apples were then juiced using a fruit juicer. The juice was left to stand for approximately 15 minutes so that the solids could settle. The liquid portion of the raw juice was then poured into vials and stored for a few hours to a day, until further analysis could be performed.

Sugar:

Sugar analysis was performed using a Struers BS Automatic Refractometer (RFM 90). The SSC was expressed in Brix. Sugar measurements were taken on two samples from the juice from each apple. Three measurements were taken if the two measurements varied greatly. These measurements were averaged to arrive at the final soluble sugar content data used in the data analysis.

Figure 12. Juice samples.

Acid:

Acid and pH measurements were derived by titration. A 719 S Titrino was used for measuring acidity. Fruit juice acidity was obtained using a NaOH 0.1 N. Results were expressed in grams of NaOH needed to titrate 100 grams of fruit juice until pH's solution reached 8.1 and using the pH scale.

DATA ANALYSIS

The UNSCRAMBLER software (Camos AS, Norway) was used for the multivariate data analysis. Matlab R.12 (The Math Works Inc., Natick, MA) was used as a bridge program between the spectrometer outputs and Unscrabmbler to transfer the reflectance data to be analysed. SAS (v. 8.2, SAS-Institute, Cary-NC) was used to run the ANOVAs.

Data was analysed using both simple statistics and multivariate analysis. Analysis of Variance (ANOVA) was performed on all the variables. The level of significance was assumed to be $p=<0.05$.

Multivariate Analysis:

Multivariate measurement involves the measurement of more than one variable or response for each sample. The main goals of multivariate analysis are to describe data, discrimination and classification and regression and prediction (Esbensen *et al.*, 2001).

Multivariate analysis of NIR data can be classified in the discipline chemometrics. Chemometrics is the application of statistics and mathematical methods to analytical chemistry. The aim of chemometrics is to display data in ways that allow chemical interpretation of the system being analysed. This may involve transformations of the original data or deriving new variables that are functions of the original data (Abu-Khalaf, 2002).

A model is a mathematical equation that summarises variation in a data set. Models are built to clarify and understand the structure of the data. Statistical models consist of two parts:

1. Structure (information) and
2. Error (noise, the random variation that does not contain information)

The structure of a model can be used for interpretation or prediction. The noise should be as small as possible to consider the model as reliable. The purpose of multivariate modelling is to separate information from noise (Esbensen *et al.*, 2000).

The best multivariate models are those which have (Abu-Khalaf, 2002):

1. Low RMSEP (Root Mean Square Error of Prediction)
2. High correlation coefficient (r) between the predicted and the measured values
3. Low number of latent variables
4. Low difference between RMSEP and RMSEC (Root Mean Square Error of Calibration) values (A large difference indicates that the calibration set doesn't represent the validation set.)

However, choosing the most appropriate model depends on the parameters being analysed and the goals of the analysis (Esbensen *et al.*, 2000).

Modelling of the data was attempted using principal component analysis (PCA). PCA is modelling of one x-matrix. PCA was used to develop a model for the key variables that may predict the internal quality of apples: dry matter, firmness, sugar (SSC), acid and the ratio of sugar to acid. PCA reduces the dimensional space of the data without losing information. PCA removes redundancy from the data set from correlated variables (Esbensen *et al.*, 2000). This is a bilinear method of modelling. It gives an overview of the main information of a multidimensional data set by projecting the original variables' information onto a smaller number of underlying variables (latent variables) that called principal components. The interrelationships between different variables: groupings, similarities, differences and patterns, can be determined by plotting the principal components.

Multivariate calibration modelling was also used to analyse the data. Multivariate calibration modelling is used to relate two data sets of dependent (Y) and independent variables (X) by regression (Esbensen *et al.*, 2000). Partial Least Squares (or Projection to Latent Structures, PLS) regression methods were used for multivariate calibration during the data analysis. Partial Least Squares Regression allows the Y-data structure to intervene directly in the X-decomposition. PLS1 models one Y-variable and PLS-2 models several Y-variables simultaneously.

Classification modelling is used to recognize patterns in the data. Soft Independent Modelling of Class Analogy (SIMCA) and Partial Least Square – Discrimination Analysis (PLS-DA) was used to classify the apple data. These types of classification are based on separate PLS models. The SIMCA analysis is illustrated as a Commans plot.

Three transformations of our data were used to clarify any patterns in the data. The raw data was first analysed. Then multplicative scatter corrections (MSC) and first and second derivative transformations were preformed. A second derivative transformation was performed for the SIMCA classification and the PLS-DA and MSC was used with the SSC model.

Results

Significant differences between organic and conventional apples were found for the sugar and acid ratio (ANOVA, p=0.04), volume (ANOVA, p=<0.0001) and the colour variables (ΔE_{ab} (ANOVA, p=<0.0001), the difference between the combination of all colour variables for each apple and the reference, ΔL (ANOVA, p=0.01), the difference of lightness between data for each apple and the reference, ΔC (ANOVA, p=<0.0001) the difference of the saturation between data for each apple and the reference). All other variables were not found to be significantly different dry matter (ANOVA, p=0.74), firmness (ANOVA, p=0.41), sugar (ANOVA, p=0.51), acid (ANOVA, p=0.18), pH (ANOVA, p=0.29), ΔH (ANOVA, p=0.52), the difference between the hue for each apple and the reference, and ΔH° (ANOVA, p=0.85), is ΔH recorded as an angle (raw data presented in Table 3). The mean spectra for all conventional and organic apples differed (Figure 13).

The score plot (Figure 14) for the principal component analysis of all internal variables for the raw data suggests that the first principal component explains most of the variation in spectra (97%). Figure 14 shows that conventional apples tend to have scores more to the right for PC1 and organic apples tend to have scores to more the left. This suggests that the first principal component is related to the production system. The plot of the residual variance for the PCA model of the internal variables (Figure 14) shows that one PC explains most of the variation in the data. The loading plot (Figure 15) shows that the NIR data are not explained by the second principle component and that they are only slightly explained by the first principal component. The acid and pH variables are explained well by PC2 but not by PC1, firmness is explained less well by PC2 and not by PC1 and sugar and dry matter and mostly explained by PC2 by may be slightly more related to PC1.

The raw data and second derivative (d^2log1/R) transformation models predicting SSC showed the best correlation between the measured and predicted variables. However, for all transformations tested the correlations were lower that reported in the literature. The highest correlation was found for the second derivative model (Figure 17). The correlation was found to be 0.74.

The Coomans plot (Figure 18) for the NIR data showed some classification at the 25% significance level. This classification rate was low, however, it does suggest some trend of segregation in the data. The Coomans plot was poorly modelled as too few principle components were used. The PLS-DA shows a higher segregation potential (Figure 19) with all but one sample being correctly classified, having predicted y-values above or below 0.5. However, this classification method depends on the pre-assignment of dummy variables (in this the production methods). There is potential to be able to classify the data using NIR data.

Table 3. Mean values plus or minus the standard deviation for raw data for the internal and external parameter components sugar, acid, pH, sugar-acid ratio, dry matter, firmness, volume and colour.

	Dry Matter (%)	Firmness (kg/cm^2)	Sugar (Brix)	pH	Acid (%)	Sugar-Acid	Volume (cm^3)	H° (degrees)
Conventional	15.4±1.7	5.5±2.5	12.1±1.3	3.9±0.1	0.34±0.06	36.6±7.0	156.5±18.4	18.6±3.2
Organic	15.4±2.2	5.2±1.7	12.0±1.7	3.8±0.2	0.32±0.10	39.1±9.6	126.7±15.1	18.5±7.9

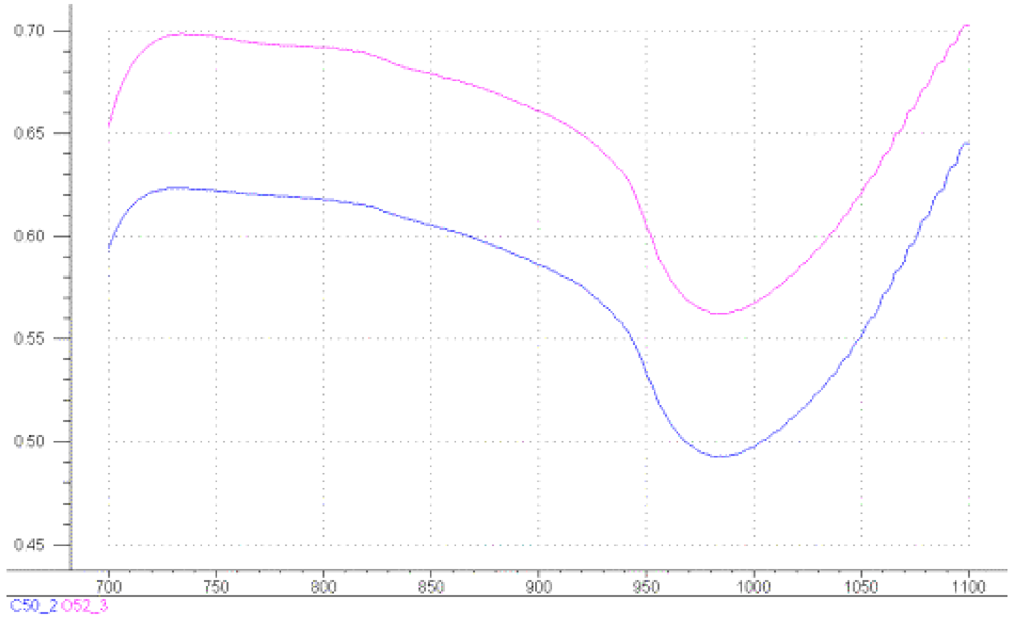


Figure 13. Mean of spectra for conventional and organic Golden Delicious apples.

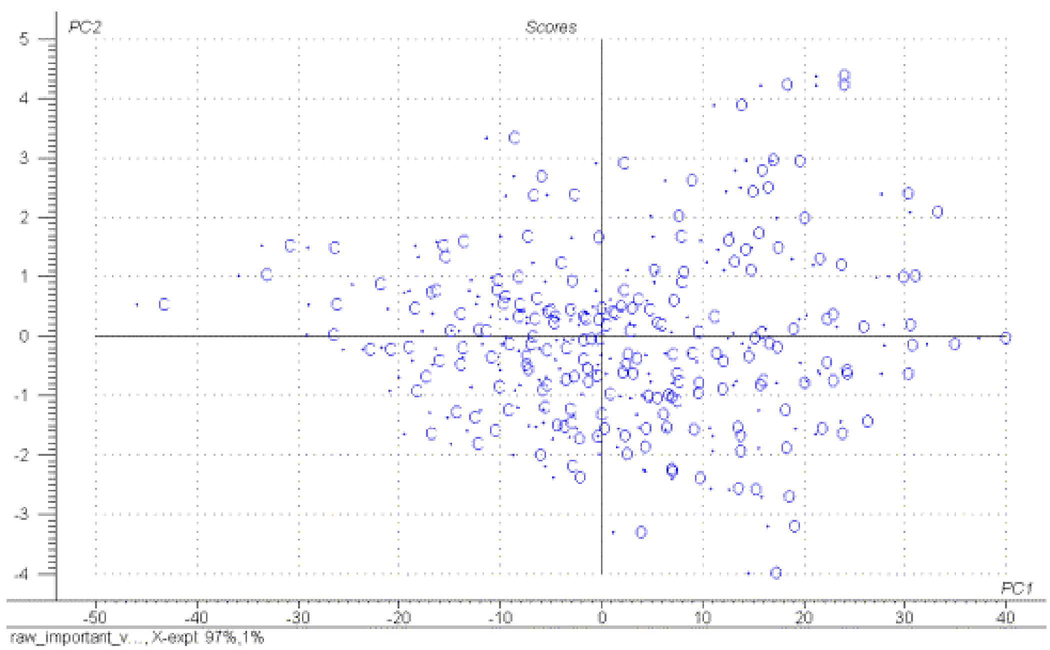


Figure 14. Score plot of Principal Component Analysis for Golden Delicious Apples. Showing that organic and conventional apples vary along the first principal component.

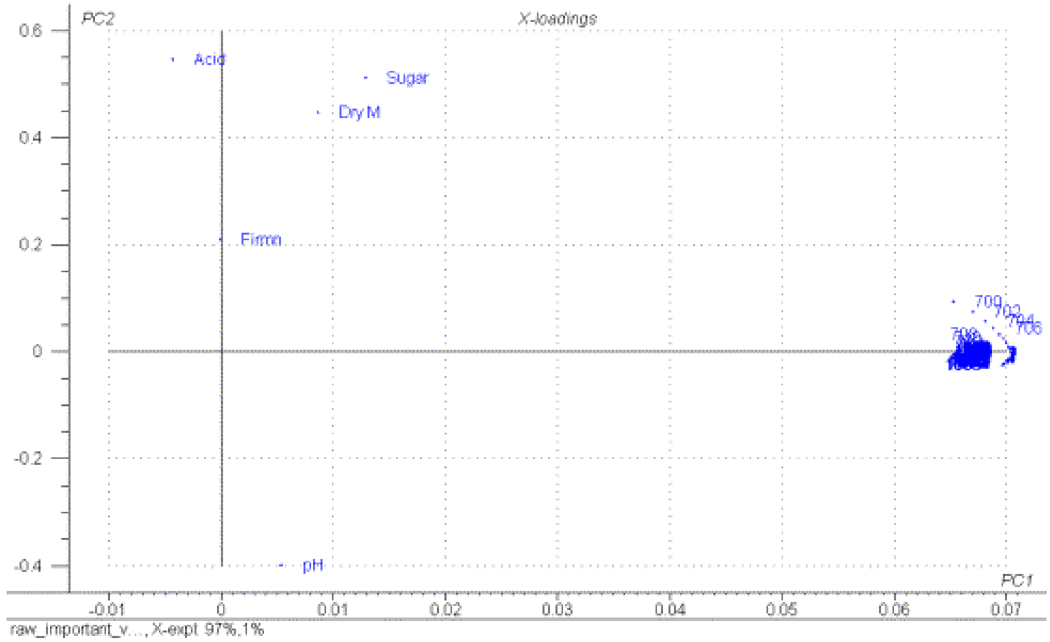


Figure 15. Loading plot of PC1 and PC2 for the Principal Component Analysis for all internal quality variables measured in the comparison of Golden Delicious apples.

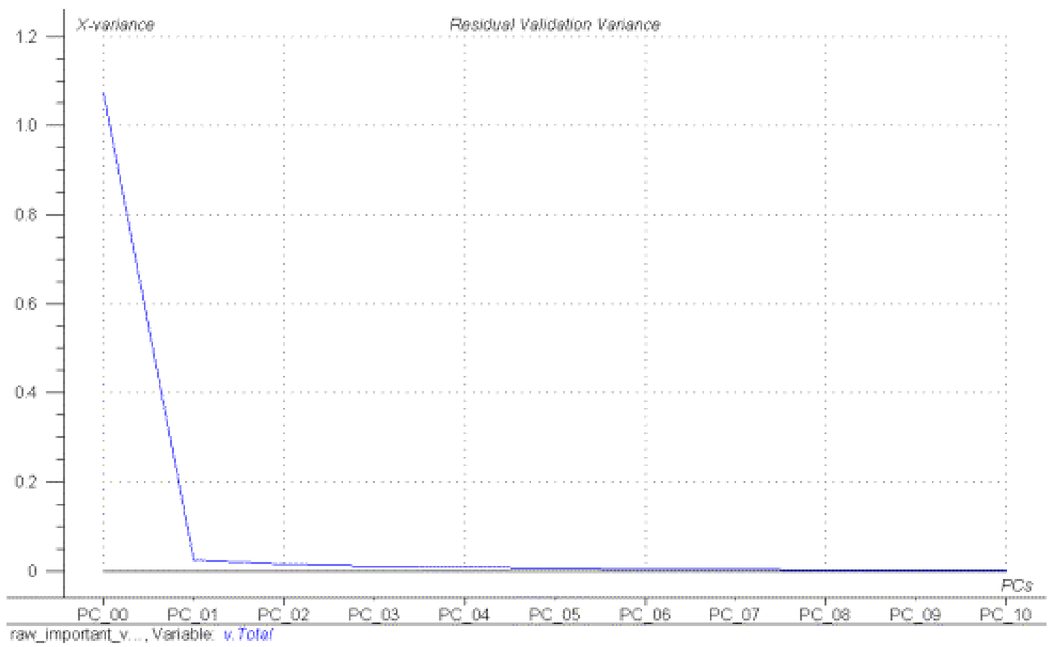


Figure 16. Residual variance for PCA of raw data showing that data is best explained by one principal component.

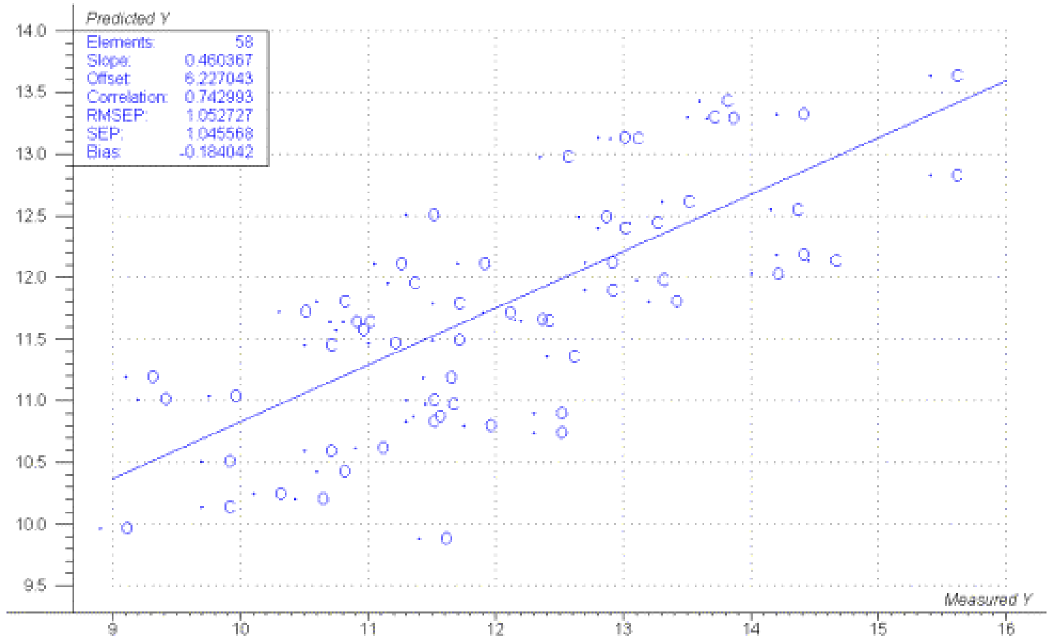


Figure 17. Model test set validation for the prediction of SSC levels based on NIR spectra. This model shows a correlation of 0.74. (PCs = 5)

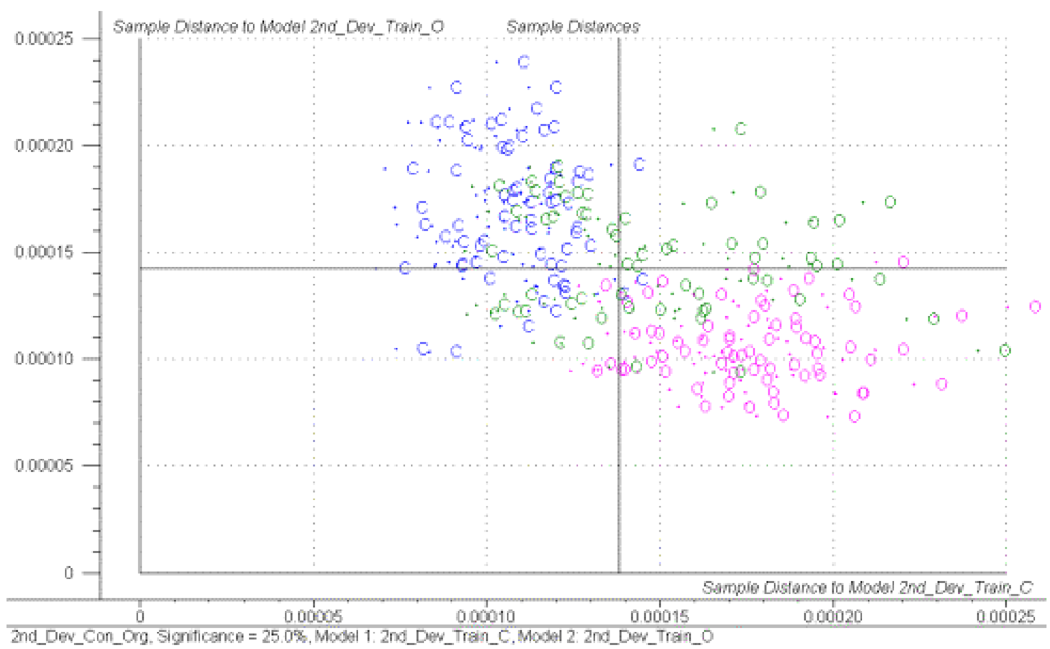
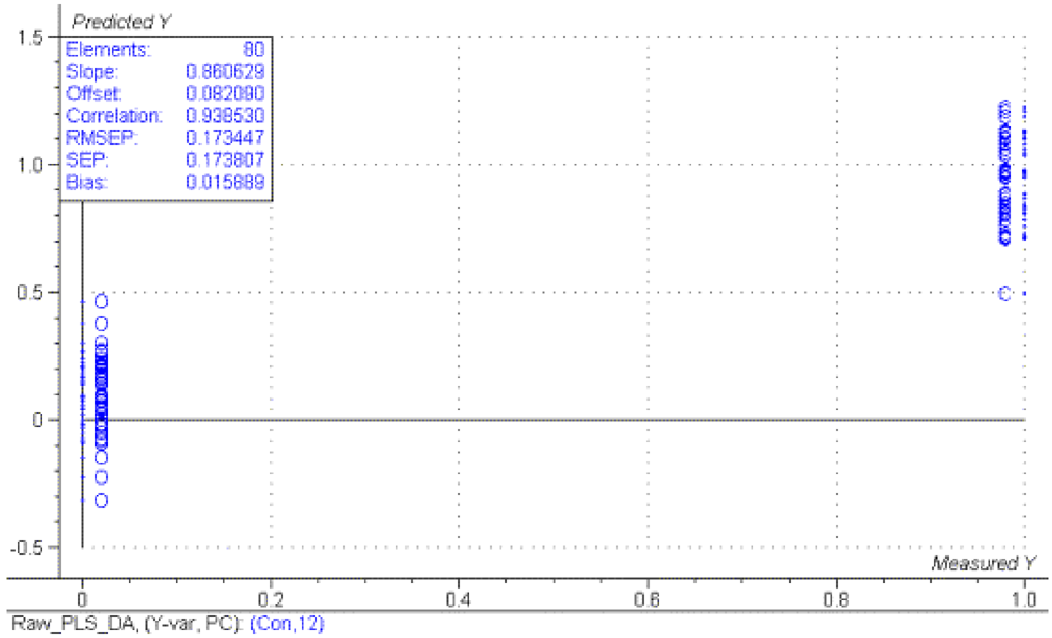


Figure 18. SIMCA classification of data with a second derivative transformation for organic and conventional Golden Delicious apples. Coomans plot of a showing the partial segregation of the data. (PCs = 5)

Conventional Apples



Organic Apples

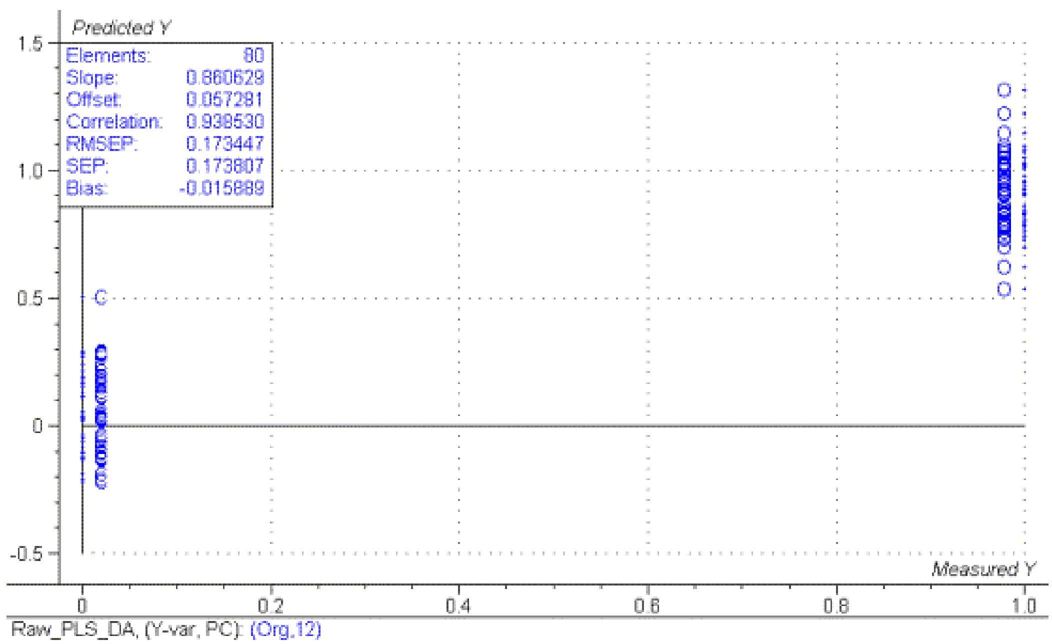


Figure 19. Partial Least Squares Discrimination Analysis for organic and conventional Golden Delicious apples. All but one sample have predicted y-values above 0.5 when compared to the other production system suggesting correct classification. (PCs = 12)

Discussion

The significant difference in colour and volume may be due to the production method or may instead be due to climate and other farming practices. The variable fruit size has been shown to relate to the growing climate (Kays, 1999). Difference in volume may, instead, be due to sorting of the apples. Even though, both organic and conventional apples were labelled as class one they may have been sorted into different volumes within this class. The first principal component, that explains most of the difference between the apples, is suggested to be production method. However, this PC "production method" may have nothing to do with organic versus conventional production.

Though the sampled organic and conventional apples were different in appearance, no difference in internal qualities that could contribute to nutrition or taste of the apples could be shown. This is consistent with the results of Vetter *et al.* (1983 in Woese *et al.*, 1997) and Reinken *et al.* (1990 in Woese *et al.*, 1997) that the concentration of dry matter and the sensory properties of apples did not differ. However, our results differ from the findings of Reganold *et al.* (2001) and Wiebel *et al.* (2000), who found significant differences in internal quality parameters. Based on our results and the variability of the findings in the literature, none of the tested variables can be considered to differ consistently between organic and conventional production, for Golden Delicious apples. There may be no non-appearance qualities that consistently differ between organic and conventionally produce apples.

The correlation of SSC for PLS-1 ($r^2 = 0.74$) was found to be lower that other reported findings (Abu-Khalaf, 2002). This may be due to error in our experimental procedure or to differences between our experimental procedure and that used by other researchers. For example, Ventura *et al.* (1998) took cores from the apples for sugar analysis from the same area as NIR measurements were taken. This should mean that the Ventura *et al.* SSC and NIR data are better correlated. The sugar content of apples has been shown to be variable (Moons and Sinnaeve, 2000). This suggests that our experimental procedure of only using an average of three spectral measurements to represent the whole fruit should reduce the correlation of the NIR spectra to the SSC of the juice collected from three-quarters of the apple. The juicing method, its self, may have been inaccurate as the apple flesh was pulverized and then most of the solid matter was removed. This removal of the solids may lead to changes in the concentration of SSC and acid.

No significant correlation was found for variables other that sugar. This is consistent with the findings of other researchers. Some have been able to find correlation for acid content (Peirs *et al.*, 2000). However, correlation of NIR and firmness of apples by other researchers has met with limited success (McGlone and Kawano, 1998). This suggests that the only tested variable that contributed to differences between NIR spectra for all apples was sugar.

The Coomans plot did not yield very segregated grouping of organic and conventional apples. This could suggest that using our methods for our apples classification by production method based on NIR spectra and our statistical models would not be very successful, which would not support the use of NIR spectroscopy for fruit grading. Even if the lack of classification in our experiment was due to experimental error, it is likely that similar levels of error would occur in an industrial setting. However, the classification model was based on too few principal components. The PLS-DA classification provided much better segregation. Therefore, based on our findings there is high potential for classification of organic and conventional apples using NIR spectroscopy.

Conclusions

This experiment shows significant differences between organic and conventional apples for the parameters volume, colour and the sugar-acid ratio. The volume and colour are external parameters that effect appearance. The sugar-acid ratio is the internal parameter with the greatest impact on taste. Weak correlation was shown between SSC and NIR spectra. There is potential for classification of apples based on NIR spectra.

8. Discussion and Conclusions

Survey respondents purchased organic food because of health and environmental concerns. Consumers buy organic produce because they perceive a difference in food quality. When asked to define food quality, each consumer focused on a few specific parameters. Therefore, the consumers surveyed in this report do not have a clear understanding of the entire definition of food quality. When discussing food quality, respondents were mostly concerned about sensory parameters, followed by food safety and nutrients. These parameters have been examined by a substantial amount of research. Differences between organic and conventional produce have been shown for the variables: vitamin C, nitrates and pesticide residues. Higher vitamin C contributes the nutritional value of organic produce. Higher pesticide residues and nitrate impact on food safety of conventional food. If these differences are significant than organic produce is, in fact, healthier. Our market supply experiment suggests that the organic apples sampled were smaller, had more colour variation and had a higher sugar acid ratio. However, these sensory attributes cannot be used to definitively characterise food quality, because they are very subjective. Some people may find smaller more coloured apples with a higher a sugar acid ratio to have better taste and others may find the opposite or may not be able to differentiate. Many responses from our survey state that taste and appearance are very important factors influencing their purchase of organic food and are elements of their food quality definition.

Each reviewer of the literature has come to a slightly different conclusion with respect to the variables that he or she examined. These assertions vary from those that state unequivocally that there are no differences (Williams et al., 2000 and Kumplulainen, 2001), those that hesitantly suggest that organic food is better (Woese *et al.*, 1997; Brandt and Mølgaard, 2001 and Worthington, 1998), to those that state confidently that organic food is better (Heaton, 2001). These authors have used the same papers in their reviews and have come to different conclusions with respect to food quality. The final assessment of food quality is subjective.

No difference:

Organic food may contain a higher dry matter level, as expected from the expected differences in nitrogen supply and the growth rate of organic crops. Organic food can also contain a higher percentage of nitrate and vitamin C, possibly associated with the higher percentage of dry matter. Otherwise there is no evidence for consistent differences, and in total, there appears to be no good basis for the claim that organic food is of higher quality in its composition.

Williams *et al.*, 2000

In terms of most nutrients and contaminants, no consistent trend of differences can be established in chemical quality between organic and traditionally grown foods. However, despite heterogenity the material and research methodology, certain differences in the chemical quality between conventionally grown foods and those produced by organic farming can be identified. The clearest difference appears to be the higher protein, nitrogen and nitrate contents of conventionally grown plants compared with those cultivated organically.

Kumpulainen, 2001

Hesitant Difference:

Despite the heterogeneity of the sample material, some differences in quality between products from conventional and organic farming or foods produced with the aid of different fertilisation systems have been identified.

Woese *et al.*, 1997

There is ample, but circumstantial, evidence that, on average, organic vegetables and fruits most likely contain more of these compounds (nutrients) *than conventional ones, allowing for the possibility that organic plant foods may in fact benefit human health more than corresponding conventional ones.*

Brandt and Mølgaard, 2001

In summary, from the research that has been done, it appears that organically grown crops may have, on average, a higher nutrient content that crops grown with chemical fertilizers and pesticides.

Worthington, 1998

Confident Difference:

Viewed collectively the valid and relevant scientific evidence indicates that organically grown foods are significantly different in terms of their safety, nutritional content and nutritional value from those produced by non-organic farming.

Heaton, 2001

In order to conclude our comparison we posed the following questions.

1. Is there any difference between organic and conventional fruits and vegetables?

Based on the results of our literature review and experiment we conclude that there are substantial differences between organic and conventional fruits and vegetables. They differ with respect to production method, labelling, marketing, price and potentially other parameters.

2. Is there any difference in the quality of organic and conventional fruits and vegetables?

Before answering this question we need to clarify our understanding of food quality. In the context of this paper, we are defining food quality as a subjective evaluation of product characteristics. The groups of characteristics that relate to food quality are safety, nutrition, functionality, organoleptic properties, ethics and authenticity. We can evaluate the difference in product quality by examining each of these parameters separately.

Safety: Organic food has less pesticide contamination. The contamination is often below levels considered dangerous for health, however these levels are set arbitrarily.
Nutrition: Vitamin C was found to be higher for organic food, no further conclusions can be made.
Functionality: Not investigated.
Organoleptic properties: Studies show varied results.
Ethics: Not investigated. Though, many people surveyed stated that organic production has less negative impacts on the environment and is socially better.
Authenticity: Not investigated.

Food quality is a weighted sum of all these parameters. The importance placed on each parameter is based on the consumers' priorities and values. In our comparison of food quality we place high importance on safety, nutrition and organoleptic properties. Based on these properties we find that organic food has higher food quality in general. It is potentially safer, may contain more vitamin C, is more ethical (environmental concern, local marketing and production) and may have better sensory properties. For instance, even if half of the studies report no difference between organic and conventional food for a given parameter, this can be interpreted as a significant difference, half of the time. If, for example, only 50% of consumer purchases of organic apples have less pesticide residues, the overall toxin consumption will still be less than in a conventional apple diet. This would imply an overall higher food quality in the organic apple diet when comparing the safety parameter of food quality. For this reason, we conclude that organic food is of a higher food quality.

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