Scripta Horticulturae
Number 16

The Interdisciplinary ISAFRUIT-Vasco da Gama Process and its Resulting House of Quality Method:

The next step towards sustainable fruit production while addressing consumer demands with critical problem-oriented research

ISAFRUIT PROJECT

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ISHS

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The next step towards sustainable fruit production while addressing consumer demands with critical problem-oriented research

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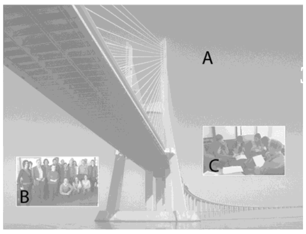

A. The Vasco da Gama Bridge spans the Tejo River in Lisbon, Portugal. As its namesake, the Portuguese Explorer who travelled the widest Oceans, the Process described in this *Scripta* aims at bridging conceptual distances between Social and Natural Sciences (Photo by courtesy of Martin Rosen, San Francisco, CA, USA).
B. The participants of the VdG launching Workshop, Schiphol, Amsterdam, March 31st, 2008.
C. Work at the VdG Workshop of March 24th, 2009, Schiphol, Amsterdam.

One of the objectives of the Vasco da Gama process was to build bridges between ISAFRUIT social science and natural science specialists, to facilitate an interdisciplinary, impact-oriented team work approach in developing sustainable fruit growing and conservation technology. A systematic, science-based response to consumer demand was – on one side – an innovative element in the sustainability concept applied by ISAFRUIT, while it was an enormous but enriching challenge to be made real on the other. This Scripta volume tells the story and details and explains the main outcomes of the process that guided ISAFRUIT to develop a science-based methodology for coping with this challenge, called the Vasco da Gama process. The process was concluded at Lisboa at a workshop held within the International Horticultural Congress, IHC 2010. That the extraordinary Vasco da Gama bridge happens to be a Lisboa landmark is a somewhat amusing situational coincidence. And why "Vasco da Gama – process"? Read more about it in this Scripta volume.

See also: www.isafruit-vdg.ch

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The VdG participants at the Workshop on Oct. 10th, 2009, Schiphol, Amsterdam.

Inspired by Don Vasco da Gama: Why Build a House of Quality for Applied Fruit Research?

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INTRODUCTION

Are you interested in human beings, even when these are scientists? This article is more about the behaviour of and interaction among scientists than science-based solutions for technical problems. It is about why and how specialists from the fields of technical and consumer-related science, can come together in a truly interdisciplinary fashion, to discover surprising new territories and common ground related to a challenge, such as increasing fruit consumption. Interdisciplinary communication can be quite complicated, however, if this challenge is managed productively knowledge gaps can be identified and new solutions developed.

This article aims to portray the deeper rationale behind the ISAFRUIT Vasco da Gama-process, to deliver a greater appreciation of the other articles in this *Scripta Horticulturae* volume and so provide insight into an approach that could improve the way that future interdisciplinary projects function.

WHY?

The goal of ISAFRUIT, an integrated project in the Farm to Fork call of the EU 6th FP, is to increase fruit consumption. This goal has strong foundations in new knowledge created by a multidisciplinary team of natural and social scientists, who have been addressing critical aspects and solving the problems within the multi-faceted fruit chain. The ultimate aim is to deliver fruit and fruit products to consumers that respond to and stimulate demand and consumption. Bridging the gap between disciplines proved to be a substantial challenge for ISAFRUIT. After two years of the ISAFRUIT project this gap was not automatically bridged simply because specialists of various disciplines were working towards a single project goal. Most likely this is attributable to the fact that the disciplines involved have quite different languages, methods and networks. A task force was needed to encourage consumer and technical scientists to interact.

In March 2008, ISAFRUIT launched an initiative to address the interdisciplinary gap. On this occasion a reservation was made for a meeting room at the BIMS world meeting centre at Schiphol airport in The Netherlands, which was labelled with the name “Vasco da Gama”. The initiative launched at this meeting was subsequently named the “Vasco da Gama process”. Early in the 16th century Vasco da Gama, the Portuguese explorer, embarked in the first ships to sail directly from Europe to India and to bridge the gap between continents and cultures. This ideal captured the imagination of the ISAFRUIT researchers participating in an initiative to link technical and consumer-related sciences, as they hoped to mirror the successful bridging efforts of Don Vasco da Gama. The motivation factor of discovering something new was not the most essential driving force behind the Vasco da Gama-process, but it was an important one.

ISAFRUIT's process for bridging between research disciplines aimed to discover if the technical research conducted within the project had addressed the consumer-demand related requirements that had been discovered by the social scientists in the projects and to see if this combined research could contribute to increased fruit consumption in Europe. Technical fruit research is a long-term business and research agendas do not have a yearly flexibility. So the question was whether the ISAFRUIT research agenda had addressed the consumer preferences of tomorrow and the consumer's acceptance of desired innovations within the next 3 to 5 years.

The precisely planned project defined many deliverables for its technical and social science related sectors, even including interdisciplinary participation in the elaboration of these deliverables. It became evident in the first two project years that these deliverables were principally driven by the thinking of the principal technical or social scientists, while a mutual working philosophy and understanding was lacking. Retrospectively, this is understandable. Nowadays the research continuity is constantly endangered by increasingly reduced core funding, forcing disciplinary researchers to depend more on project funding. This leads them to address the long term goals of their institutions and disciplines by stepwise addressing those goals with projects of quite limited time and scope. If interdisciplinary exchange is not a strong driver among these long term goals, it is difficult to give it the focus required within a project like ISAFRUIT, which actually relies on such interdisciplinarity. Also, there was some imbalance at the beginning of the project between the expectations of technical and social scientists. Technical scientists expected guidance and participation from consumer scientists in order to orient their research, while consumer scientists first had to develop some of the knowledge needed. Both parties had difficulties to communicate, since they were talking in different terms and about different things.

In the first two years of ISAFRUIT the project reviewers had not asked for documented, systematic proof of the potential impact of technical studies on consumer behaviour. This may have been a reflection of their own expertise and expectations. Also, they might have been overwhelmed by the impressive amount of technical data and interesting partial results produced in the first two project years. At that time, the question of how technical and consumer studies might indeed impact on consumer behaviour and contribute to increased fruit consumption had therefore hardly been asked. All activity was consequently embedded in the well documented project concept, the technical bottlenecks were clearly defined, the respective objectives formulated, the project plan, now being implemented, was accepted. However, while the project was proceeding, it became difficult to get an overview of its overall progress, even though progress was recorded in detail in the project reports. The fact that reports had to be delivered on a yearly basis while planning had to be made for overlapping 18-months planning periods also contributed to this difficulty. Hence, some ISAFRUIT scientists were concerned and questioned whether the ambitious project would be able to reach its goals if it proceeded according to the project plan. This provoked them to react and address this difficulty. It became rapidly evident that this was not a simple problem to be solved in one simple action and so the Vasco da Gama-process was born.

This article will present some insights into the genesis of the Vasco da Gama-process and an emerging methodology, which could quite substantially re-orient the concepts and procedures in horticultural and agricultural research. It reveals how a group of open minded scientists with the ambition to understand each other developed a common language and understanding and nourished the Vasco da Gama-process. This energy still drives this process: it is the pure (and indeed research-related) fun and curiosity of ploughing new ground, in an energetic working environment, while walking on the edge of breaking new discoveries (at least: thought to be), armed only with an open mind and a willingness to understand others from different disciplines.

HOW?

For the Vasco da Gama team the essential question was: is there a science-based method with which one can validate "*ex post*" technical research findings, i.e., findings that have already been obtained, with respect to their relevance to addressing consumer demands? What if we realized by the end of the project that all money was spent and we lacked a methodological approach for verifying whether a particular technical experiment had contributed to the overall objective of the project?

This was basically an *ex post*-type question which in technical science is not very common. We are used to designing an experiment for the purpose of testing a hypothesis, i.e., validating *ex ante* the results. In this case, the experimental designs of many ISAFRUIT studies were fixed and the immediate results were on paper. As technical results were already there, it was not possible to study consumer preference related aspects simultaneously with or *ex ante* of a technical study. It was for many of us quite an atypical setting, and we asked ourselves: are we already too late to be able to verify whether ISAFRUIT technical experiments have contributed to an increase in fruit consumption in Europe?

How was a method which addressed our concerns found? The Vasco da Gama-process story is a reaction to a self-imposed intellectual pressure among several of ISAFRUIT Management Committee to find a solution for preventing project failure. They had come to the conclusion that additional effort was needed to enable delivery of what the project plan had promised.

The ISAFRUIT process for bridging between research disciplines was aimed at discovering if the technical research conducted had indeed addressed consumer-demand related requirements and was therefore likely to contribute to increased fruit consumption in Europe. Some of us had called on the need for such a study and methodology during ISAFRUIT general assembly in 2007. In the second project year, discussions started within the ISAFRUIT Management Committee that the interaction between disciplines was not satisfactory. At the midterm of the project, it seemed that while interactions increased between work packages (representing sectors of technical or social sciences), interactions between pillars (representing larger sectors of technical or social science) were lacking. The rising importance of whether ISAFRUIT could prove that technical studies did indeed respond to consumer demand led to a first workshop in March 2008. The innovation potential of a new method that would provide a science-based methodology for validating and orienting technical research, according to societal parameters (consumer demand-related attributes), stimulated and motivated a selected group of ISAFRUIT scientists from the Management Committee and the work packages to participate. They had a background of horticultural sciences, economy, consumer sciences and communication. An exploratory spirit for making breaking discoveries was in the air, when these people met in March 2008 at Schiphol airport in presence of the project coordinator and director. This was to be followed by several additional workshops, individual work or joint work with a colleague.

GENESIS: UPS, DOWNS AND DIFFICULTIES

Before the workshop in March 2008, a methodology concept was developed, based on common sense and structured thinking, to address the problem described above. Fruit quality attributes were listed. An inventory of ISAFRUIT experiments addressing the challenges of pre- and post-harvest apple production and the effects of altering these quality attributes was established. Then, it was intended to link these alteration data with attributes that relate to motives and barriers of fruit consumption, as defined by consumer scientists. This ‘pre-Vasco da Gama process’ initiative emerged and was mainly driven by a Management Committee member from technical sciences.

The concept seemed reasonable and potentially useful. However, as yet it was not developed to the necessary extent and lacked the recognition by the different disciplines which was necessary for application and ultimately, creating impact. How could we overcome this drawback? More scientists from the consumer science field needed to be motivated and involved. The methodology needed to be credible and the result of a common process for the creation of the necessary impact. Since time pressure for a solution was rising, increased efforts eventually provoked a useful solution: a search for an established, supportive concept and methodology was performed by a Management Committee member representing consumer sciences. This resulted in the discovery needed: a technique, called “Reverse Engineering”. Reverse Engineering lead us to a method, called Quality Function Deployment (QFD), including the construction of a House of Quality (HoQ). Such a house has many similarities with linking altered fruit quality attributes with motives and barriers of fruit consumption. It was “the wheel” that we had been in the process of reinventing! Luckily, we found it.

In the next chapter you can read in more detail what Reverse Engineering, QFD and a HoQ are. However, their use is defined as follows: “By the use of QFD and the HoQ, the objective for product developers is defined in a terminology that is understandable by the developers and based directly on customer needs” (Bech, 2000). The developers were in our case horticultural researchers, while those translating the consumer needs were ISAFRUIT consumer scientists. Furthermore, “The QFD process and the House of Quality tool can be applied in most any industry to increase quality and better meet the needs of its customers” and: “The House of Quality matrix is one of the best tools available for clarifying the voice of the customer" (House of Quality Online, 2008). The HoQ "is a table that connects dots between the Voice of the Customer and the Voice of the Engineer" (QFD Institute, 2010).

Did we need anything else than such a universal methodology for verification of whether we were addressing consumer demands? For more details, see the next chapter. At this point, we just want to say that we were happy to have found a methodology, which seemed to address our problem. We were foreseeing a conceptual and graphical tool that presented the positive and negative relationships between technical quality attributes, as studied and influenced by pre- and post-harvest experiments, and consumer-demand related attributes, as defined by consumer studies. This finding pushed the Vasco da Gama team forward. It further structured our approach and desire to develop a common language.

The principles of the HoQ seemed quite simple and convincing. However, once we had discovered the complexity of the tool, it had to be adapted for practical use and once we realized the work required to make it a useful tool, some enthusiasm vanished. Attempts to communicate the work already performed for developing the ISAFRUIT HoQ and to motivate further technical ISAFRUIT scientists to participate in the Vasco da Gama-process were quite disappointing and failed.

For instance, during a workshop at the ISAFRUIT 2009 General Assembly in Angers (France), the technical scientists were quite confused by the complexity of the method. This was most likely attributable to the fact that the core group had not yet formed a consolidated perception and comprehension of the tool. Consumer scientists were less frustrated, since they had learned a lot about technical case studies, with which the core team tried to explain the HoQ in an exemplary way. Furthermore, conceptual gaps of the tool (e.g., the placement of economical attributes in the HoQ), which prevented us from easily positioning ISAFRUIT studies led by scientists who were participants of the Vasco da Gama-process, provoked further erosion of the motivation of some of us. This volume of *Scripta Horticulturae* addresses the mentioned conceptual difficulties (see chapter by Esther Bravin et al.). At this moment it became evident, that the ISAFRUIT HoQ was far from being a completed house. It is a tool for structuring our thinking and guiding our research, but it is not a method which allows a ready-to-use application for any occasion. It will demand continued development and adaptation at the conceptual as well as the application level.

As a consequence of the ups and downs of the process, a sustained effort to lead and drive the process was needed. Particular deliverables were needed while constructing the house. These were sometimes quite difficult to achieve. The need for leadership in such a process and to keep it alive became evident on several occasions. In a multidisciplinary and multifaceted environment, the forces that could cause the process to fall apart seem quite strong, if you lose momentum. However, it was also our experience that leadership was generally and eventually rewarded by scientists from different disciplines who seemed, despite the drawbacks, quite keen to be and to remain involved in the Vasco da Gama-process.

The fun factor was an essential element in building up and keeping the momentum. For instance, we decided that the moment had come to go public and publish on the Vasco da Gama-process. ISAFRUIT was preparing for the publication of a Special Issue of the Journal of Horticultural Science and Biotechnology, for which articles had to be written. We wanted to publish an article on the Vasco da Gama-process. There were moments when we regretted committing to this, since the whole Vasco da Gama-process was superimposed on all other duties. All were absorbed by other important things, may it be another ISAFRUIT activity, other projects or, not least, holidays for not loosing self esteem and the care of family and friends. The moment had come when the article had to be submitted. However, the author team was dispersed across Europe and difficult to contact. There were still many open questions referring to the draft of the paper which needed to be addressed and answered. One e-mail of our Italian Vasco da Gama-team member at that time was: "I feel like we are really writing the script for a Bond movie with this criss-crossing of messages over Europe of ours! It's really getting to the exciting part now: Lukas is in Northern Italy by way of a bike (sorry, no more Aston Martins, we must improve sustainability!!) through a remote mountain pass to avoid being caught by the ominous deadlines set by the journal's editor (who must be our foe, not because we don't like him, but it's one of those twists of life!), and is doing so while remarkably reading mails, while Sharon (our Bond Girl of the occasion) is raising smoke curtains by flying to Denmark with a clear ISAFRUIT cover. Ivo was busy in The Netherlands and here Lukas felt he had to do something!!!" So, the Vasco da Gama-team became part of a James Bond movie, and we would certainly win the battle against the bad guy. Such a story might seem irrelevant in this context, but it is not. It reflects one aspect of the fun factor and team spirit behind the process, which was needed to bring the process forward. Miraculously, the article was finalized and eventually published (Bertschinger et al., 2009).

A last, but not the least, word about resources. The process demanded time and money. And there was no free time, no free money: even if ISAFRUIT was one of the biggest EU-projects of its time, there was no extra time and money since the project was precisely planned and resources assigned. It required a considerable effort of leadership from some of us, to find ways to allocate resources to the process, which were assigned to the process not by instantaneous occasion, but by demand-driven planning. Some resources became available due to differences between project planning and reality as ISAFRUIT evolved. Eventually, a work package was established and approved by the Management Committee, assigned to the top project management level. It described the foreseen deliverables which were produced (e.g., an ISAFRUIT Vasco da Gama-process webpage, see http://www.isafruit-vdg.ch), creating more and more evidence that something was happening. That was a good experience.

THE STATE OF THE ART

What you will discover in this volume of *Scripta Horticulturae* is as a result of the Vasco da Gama-process: a methodological answer on a fundamental question of consumer and market-oriented horticultural research, which in principle is validated although several details of the methods still need to be developed and defined.

The fundamental question: how can we make sure that technical research findings indeed address relevant consumer demands?

The achievements of the Vasco da Gama-process so far:

- Conceptually sharpened group of technical and consumer scientists, who know how the problem can be addressed.
- A methodology for addressing the question is described and published in principle. The tool of this methodology is called the ISAFRUIT House of Quality (HoQ). Some elements of the detailed concept developed have been validated by ISAFRUIT scientists, while other parts yet lack validation. Other elements have yet to be developed.
- The methodology is based on a simple concept, while the real adaptation of the simple concept to a particular situation is more complex. However, the principles of the method can be applied to any particular problem-solving situation in applied horticultural research, even if not all details of the methodology are defined in quantitative relational terms.
- The methodology draws on existing concepts and methods, such as Reverse Engineering and Quality Function Deployment. However, the ISAFRUIT team has added innovative elements to them (a Technical Experiment on Apples-House), to enable validation of the ISAFRUIT technology with regard to its relevance to addressing consumer demands.
- The impact of the work developed so far as part of the Vasco da Gama-process is that the conceptually sharpened persons will work with a quite different attitude in their technical or consumer science related environment. Also, some of the ISAFRUIT studies have been directly verified with the HoQ (see case study chapters of this *Scripta Horticulturae* volume).
- The concept and the so far defined parts of the HoQ are published and available to anybody. This will allow feedback on market and consumer-oriented technical studies from any interested scientist and policymaker. In addition, we hope to provoke discussion about any knowledge gaps that remain within the fruit chain. Together with parts of the HoQ that have yet to be validated, these knowledge gaps may be the subject of further interesting studies in the future.

The ISAFRUIT HoQ is therefore a house under construction, which must dynamically evolve. It will never be finished and never be a ready-to-use tool for un-reflected application, on any occasion. The foundations are solid, the walls are set, the furnishing placed by 80%. There is enough ground for completing the furnishing and changing it according the requirements of its inhabitants.

Acknowledgements

A force of the Vasco da Gama-process is that a large group of people with differing scientific backgrounds have contributed. The process ran over several years and the group involved in the process was evolving as well. Citing all those involved bears the risk that someone might be forgotten, so we decline this. However, this is the place to strongly acknowledge Susanna Steiner van der Kruk and Katharina Kockerols, who administered the process very actively and conveniently for all of us. Their enthusiasm and friendliness, gentle reminders, efficient organisation of workshops and

all other activities were an integral part of the process as experienced by all of those who participated and have significantly contributed to keeping the process going.

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Building and Using the ISAFRUIT House of Quality

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INTRODUCTION

Quality Function Deployment (see Hauser and Clausing, 1988) is a systematic approach to: first, translate consumer wishes into product specifications; second, to further translate these product specifications into process design and production design and planning. The approach was to support the firms' managerial decisions for consumer-driven quality improvement in evolutionary new product development. QFD is typically visualized by means of a number of subsequent houses, the first one of which is called the House of Quality (HoQ). This HoQ includes *i*) a list of identified consumer whishes (such as a sweet taste in the case of apples); *ii*) a list of product characteristics (such as sugar-acidity ratio); and *iii*) a cross-classified table of linkages that indicate whether and how the fulfillment of consumer wishes (the WHATs) is influenced by changes in product characteristics (the HOWs) (see Figure 1, which gives an overview on the ISAFRUIT HoQ). Hauser and Clausing (1988) suggest that the consumer wishes are identified by means of qualitative consumer research (e.g., in-depth interviews and small-scale observational studies) and formulated as much as possible in the language that consumers are using. The list of product characteristics typically is to be compiled by people from an R&D department. The assessment of the linkages between consumer wishes and product characteristics requires input from and discussion between both people that are knowledgeable about consumer wishes and the market, and people from the R&D department.

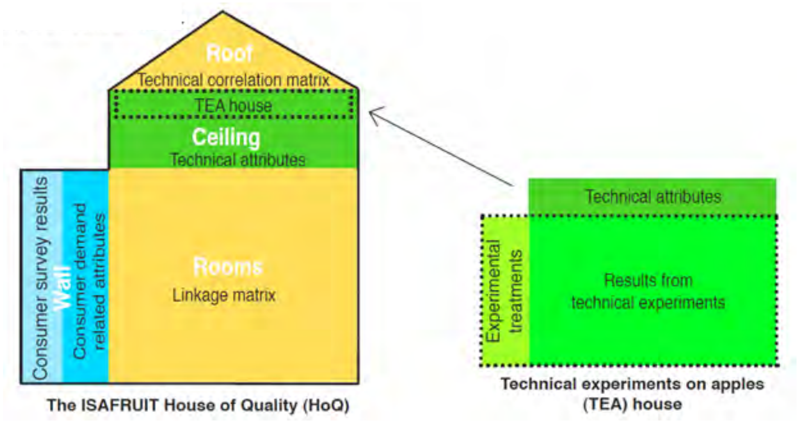

Fig. 1. Overview on the ISAFRUIT House of Quality (Andersen et al., 2010)

To arrive at product specifications from consumer wishes, a typical HoQ also includes scores for the importance of the consumer wishes (which may be specific for a particular consumer segment, like older male Danish consumers) and scores that give a competitive assessment of the extent to which consumers (in that consumer segment) perceive the own product of a firm and a number of competitor products to fulfill the different consumer wishes. In addition, a so-called technical correlation roof is constructed, in which the associations between technical characteristics are indicated (e.g., in an apple a higher acidity level goes together with a greener ground colour), including information on (in-)feasible combinations. Finally, a cellar is then added to the house. This cellar typically contains: *i*) target values/ranges for the technical characteristics; *ii*) a competitive engineering assessment in which a company's own processes and techniques are evaluated in comparison to competitor firms, and *iii*) product-characteristic importances, which are derived by combining consumer-wish importances with the linkages between consumer wishes and technical characteristics. These product-characteristic importances reflect the relevance of each of the technical attributes for the fulfillment of consumer wishes. In a subsequent house, the product-characteristics target values/ranges become the WHATs and a list of for instance process characteristics become the HOWs; links between product and process characteristics are specified which leads to target values/ranges and importances of process characteristics. In this way, QFD and the HoQ are a management tool for making consumer-driven decisions in product quality management and evolutionary new product development on the basis of a systematic confrontation of different sources of information. In addition, they facilitate communication between different departments within a firm. The translation from consumer wishes to product and process design is also labeled as "reverse engineering", which refers to the situation in which one tries to recover the building instructions when only having the completed product at ones disposal. A stepwise comprehensive introduction into the ISAFRUIT HoQ can be downloaded from the ISAFRUIT Vasco da Gama webpage www.isafruit-vdg.ch (Andersen et al., 2010).

THE CONSTRUCTION OF THE ISAFRUIT HOUSE OF QUALITY

Technical Attributes (Product Characteristics) in the ISAFRUIT HoQ

The ISAFRUIT House of Quality was built with the purpose to validate the contribution of pre- and postharvest apple experiments that had already been carried out or planned in detail, to increase fruit consumption. As such, the list of product characteristics (we refer to them as technical attributes, see the ceiling of the ISAFRUIT HoQ in Fig. 2) is limited to those technical attributes that are, or could be, influenced by the experiments, irrespective of whether being the focus of the experiment or not, and whether being actually measured in the experiment or not.

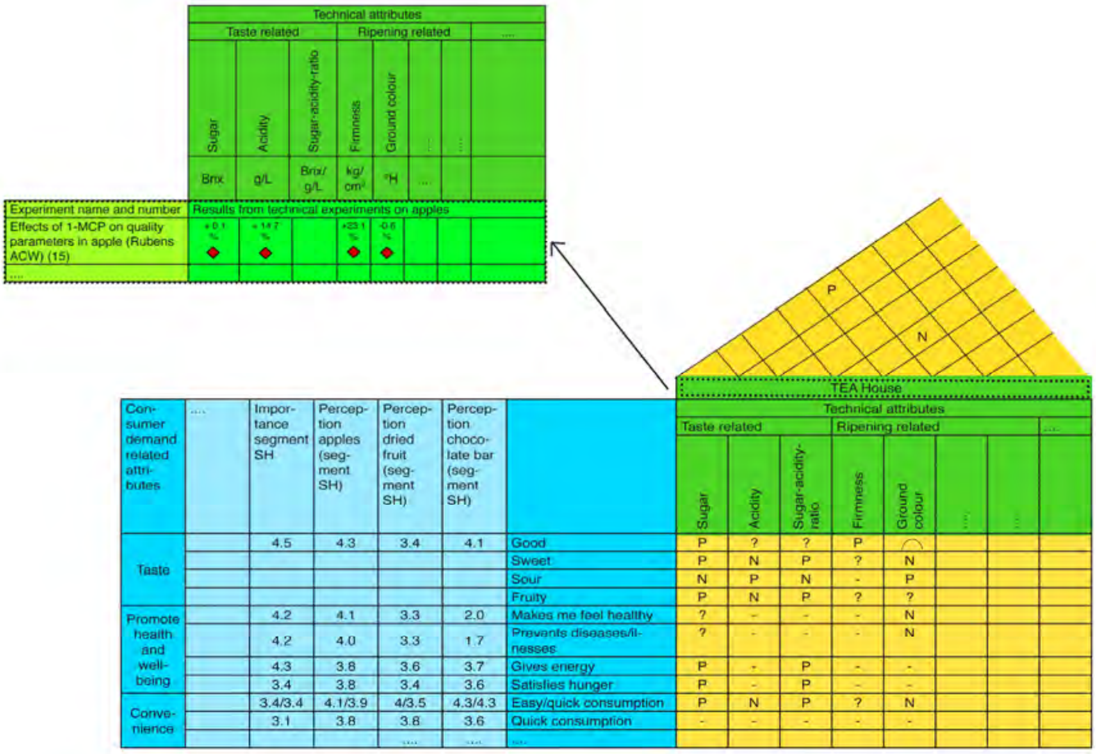

Fig. 2. Excerpt from the ISAFRUIT House of Quality, including an excerpt of the TEA house on the upper left. Note: all parts displayed are for explanatory purposes. Specific linkages and results are not suitable for referencing. For the most actual version of the House of Quality with the linkages established so far, see www.isafruit-vdg.ch.

Discussions among technical scientists involved in the pre- and postharvest experiments led to a list with 34 technical attributes, which were subsequently categorized in: Physiological and pathological disorders, Texture- and smell-related mineral components, Ripening related attributes, Taste-related attributes, Smell-related attributes, Safety- and health-related attributes, Sensory descriptive attributes, and Economic attributes. Due to the fact that we took the existing experiments as a starting point, the list of technical attributes almost exclusively consists of (intrinsic) attributes (e.g., ground colour) defining the core product, and only two (extrinsic) attributes (e.g., price) that are part of the so-called extended product[1]. From the perspective of linking technical attributes to consumer perceptions and wishes, it is useful to distinguish between: *i*) technical attributes that can be verified by consumers at purchase (e.g.,

[1]Fruit quality consists of extrinsic and intrinsic attributes. Intrinsic quality attributes are direct physical characteristics of products (e.g., taste, smell, texture etc.), while extrinsic quality attributes are related to the product, but are not a (physical) part of the product, and are generated by practical values (e.g., production method, brand, denomination of origin, traditional image, price, display of fruits at the point of sale, etc.) (e.g., see Olson and Jacoby, 1972).

size), also called search attributes, *ii*) attributes that are experienced upon consumption of the product (e.g., sugar level), also called experience attributes, and *iii*) attributes that cannot be verified by consumers (e.g., vitamin contents), also called credence attributes. The distinction is relevant because changes in credence attributes cannot directly influence consumers' perceptions. Instead, consumers need to be informed about the change (and trust the information and the source of it) or be influenced via associations that they perceive to exist with search or experience attributes (e.g., increasing the vitamin content in an experiment happens to go along with a higher acidity level and a consumer believes that a more sour apple contains more vitamins). It generally turns out to be difficult to change consumers' perception by the mere provision of information. The distinction between experience and search attributes is relevant because when consumers are dissatisfied with search attributes they can choose not to purchase or consume the apple. When they are disappointed by experience attributes, they already went at least part of the way before they can choose to stop consumption (and perhaps claim some money back).

Consumer-Demand Related Attributes (Consumer Wishes) in the ISAFRUIT HoQ

Consumer wishes (we refer to them as consumer-demand related attributes, see the left-hand side wall of the ISAFRUIT HoQ in Fig. 2) have been identified in focus groups discussions on motives for and barriers to fruit consumption, and in focus groups discussions on factors underlying the acceptance of novel fruit products in four different countries: Greece, Poland, Spain, and The Netherlands. A number of these consumer-demand related attributes had also been identified on the basis of interviews with experts from the same four countries. It took quite some effort to arrive at a comprehensive list that would be still close enough to consumer language. Decisions had to be made whether terms that consumer use should be considered as synonyms (nice, pleasant, natural smell) or not (constant over time and predictable). Decisions had to be made whether a natural smell and a natural appearance should be included in the list, in addition to natural production and processing. A decision had to be made whether ripeness should be regarded as a separate consumer-demand related attribute or as an umbrella term for good taste, juiciness, pleasant smell, and appealing appearance. Decisions had to be made whether to include feelings of doing the right thing and overall attractiveness, or whether those had to be considered as consequences of other consumer-demand related attributes. After several discussions among consumer scientists a more or less established list now consists of a total of 41 attributes in the categories: Taste, Texture/composition, Smell, Appearance, Promote health and well-being, Safe, Convenience, Price, Pleasant associations, Product differentiation, and Production.

Attribute Importance-Based Consumer Segments

A consumer survey was conducted to i.a., quantify the relative importance of 14 of these 41 consumer-demand related attributes in different consumption situations. On the basis of these importance ratings, consumer segments were derived, of which five (referred to as "Indifferent and Average", "Safety! and Health", "Convenience – Quick and Easy Satiety", "Snacking Pragmatics", and "Caring Women – Health and Feelings") were singled out as being more interesting from the perspective of increasing fruit consumption. On the left-hand side of the ISAFRUIT HoQ, one can find, for each of these segments, both mean consumer importance ratings, as well as the mean consumer perceptions[2] of apples and five competitor products (peaches, orange juice, dried fruits, chocolate bars, and salty snacks), on the 14 consumer-demand related attributes that were included in the survey.

Linkages between Technical and Consumer-Demand Related Attributes

Once the technical and consumer-demand related attributes were defined the interdisciplinary work started. Technical attributes were divided across technical scientists and consumer-demand related attributes across consumer scientists. Where the attributes of a technical scientist and a consumer scientist met each other in the linkage matrix, the two scientists were to form a tandem discussing the character of linkages. In advance, six categories were defined to characterize the linkages: Positive, Negative, Positive Ideal Point (i.e., up to some level, an increase in the technical attribute will lead to an increased fulfillment of the consumer-demand related attribute, but with a further increase in the technical attribute, the fulfillment of the consumer-demand related attribute start to decrease again), Negative Ideal Point, No Relation, and Unknown/Complicated Relation. Characterization of the linkages was as much as possible to be substantiated by specific scientific papers and/or external peer evaluation, but in absence of that could be based on the tandem members own expertise. As soon as the tandems started their journey of interdisciplinary exploration, they realized how exciting it is to discover new disciplinary continents. Sometimes, there were misunderstandings, e.g., the word "variety" (diverse assortment of fresh and processed fruit products in case of consumer scientists; a genetically homogeneous apple population in case of technical scientists) was understood and interpreted completely different depending on the expertise of the tandem partner, but those nasty surprises were always outweighed by widened knowledge and increased understanding of the complexity of the whole.

One of the encountered complexities was that the consumer perspective had to be the leading principle. Each linkage is defined as the perception from the consumer of the relation between the technical and the consumer-demand related attribute. A positive linkage would for instance mean that the more they (consumers) believe there are/is X_i (technical attribute), the more (P) they have the perception that Y_j (consumer-demand related attribute) is true. As such, it is always about the consumer's view and not about a technically confirmed view.

A second complexity was that to assess the character of linkages in a thorough way would almost require a complete literature review per linkage, something for which the time and the means were not available. Also, archiving the results from such studies

[2]In the typical HoQ, mean perception ratings are placed at the right-hand side of the HoQ. Because of the relatively large number of technical attributes in the ISAFRUIT HoQ, we felt that placing them at the right-hand side would put them too far away from the mean importance ratings, which should be considered simultaneously in a competitive assessment.

would require considerable effort. A further complexity derived from the fact that the character of a number of linkages is likely to vary across consumers, across different ranges of the technical attribute (e.g., above some level of firmness the perceived easiness of consumption will probably not be further influenced anymore), and across time (e.g., recent news items may have changed the healthy image that consumers have of polyphenols).

A different kind of complexity was that double-counting due to (so far) existing relations among technical attributes, was to be avoided. An example of such double-counting would be that the technical attribute Pesticide Residues is characterized to be positively related to the consumer-demand related attribute Appealing/Nice Appearance, *because* Pesticides Residues lower the amount of External Damages (another technical attribute) and less External Damages will lead to a perceived more Appealing/Nice Appearance. Such indirect effects had to be omitted from the tandem discussions, which was pretty hard, probably because an apple is a natural product and we are all very much used to the relations between its technical attributes. To avoid double-counting and conclusions based on indirect effects, the question that was to be answered when discussing the linkage between technical attribute X_i and consumer-demand related attribute Y_j was: "If you increase the technical attribute X_i, keeping all other technical attributes X_k in the HoQ constant, does (the idea of) an increase in technical attribute increase (P), or decrease (N), or differently affect (Positive Ideal Point, Negative Ideal Point, Unknown/Complicated Relation), the consumer's perception whether this apple is as the consumer-related attribute Y_j describes?".

On the other hand, consumer-demand related attributes are highly correlated too (tasty fruit is typically perceived to be also natural and healthy) and these correlations were to be taken into account, as they are an inseparable part of the way in which consumers perceive products. Like the linkages themselves, however, these correlations may be subject to changes sometimes in the future, for instance by the appearance of sweet green apples or by information that gradually manages to adjust consumers' perceptions and misperceptions.

USING THE ISAFRUIT HoQ

As the aim of the Vasco da Gama process was to get an overview about what we achieve in terms of ISAFRUIT's main objective, the HoQ has firstly been used to validate the contribution of pre- and postharvest apple experiments to increase fruit consumption. In the next section, the use of the HoQ as validation tool is described. The use of the ISAFRUIT HoQ for identifying gaps for future research (including suggestions for measuring additional technical attributes in apple experiments), and for policy and marketing is a possibility that needs to be further explored.

Validating Apple Experiments

Here, we are going to explain briefly the general procedure of how the ISAFRUIT HoQ can be used to provide evidence that ISAFRUIT is working in line with the main project objective. In the following chapters in this issue; this validation procedure is described and applied in the context of specific technical ISAFRUIT experiments from different work packages.

In the first step of the procedure, the technical scientists selected those attributes from the list of technical attributes that were definitely or presumably influenced by their experiment. By using diamonds of different colors, they then indicated: *i*) which selected attributes were measured and which were not measured in their experiment, and *ii*) whether the measured attributes were measured because they were a focal attribute in the experiment or because of more or less standard routines. An attribute is focal (red diamond) when one of the main objectives of the experiment is to influence it towards some target value or to keep it within a particular range. An attribute is non-focal but measured, when it is not a principal target, but routinely measured (nice-to-have information) without any effect of the experiment on it necessarily being hypothesized. An attribute is non-focal and non-measured (yellow diamond) when it is neither a principal target of the experiment, nor measured in this experiment, but evidence for a relationship between attribute and experimental treatment is proven in other experiments (within/outside ISAFRUIT). Last but not least, a white diamond is assigned to an attribute if no scientific evidence for an effect of the attribute on it is proven so far, but an effect is assumed by experts (hypothesis).

Second, consulting the details of the experimental results, the technical scientists selected a data set that best showed how a technique or cultivar influences the different technical attributes. Whenever possible, the experimental data should have been measured over several years of the project and have been shown to be quite reliable. From this dataset, the average effect of the experiment was calculated for each of the technical attributes. The observed effects in the treated units and the observed effects in the untreated units were compared for each year, and the differences calculated. The resulting annual values were converted into percentage of change and summarized for the whole period of an experiment.

Third, the average effects were entered into a new row of a table which we call the Technical Experiment on Apples (TEA) House (see Figs. 1 and 2). In QFD, this TEA House appears under names like Deployment Matrix, Product Design Matrix, and Parts Deployment Matrix. The TEA House has a column for each technical attribute and a row for each additional experiment. The colored diamonds that indicate whether an attribute is focal or non-focal, measured or not measured, and for which the effect of the experiment is supported by empirical evidence or just hypothesized, were also added to the cells of the TEA House.

After having linked the technical experiments to the technical attributes in the TEA House, technical scientists and consumer scientists used the linkages in the HoQ to assess which consumer-demand related attributes were affected by the changes in the technical attributes. Combining this information with the importance of these consumer-demand related attributes for different segments, it was possible to explore for which consumer segments the technical experiment might give an overall more attractive product, and for which consumer segments they might give a less attractive product. The more a technical experiment changes the technical attributes in such a desirable direction that the most important linked consumer-demand related attribute are on average better met in one or more consumer segments, the better the preconditions for consumers selecting the experimental apple when it would be available on the market. At the same time, it is crucial to keep track of whether there are any segments for which the overall attractiveness decreases. For those segments, the old apple might still be the better offer.

Evaluating the way in which the most important consumer-demand related attributes are affected in relation to the segment-level consumer perceptions of current apples and competitor products, will give an indication if, or for which consumer segments, the experimental apple is more likely to snatch its market share from other apples, from other fruit products, or from (healthy or unhealthy) non-fruit products.

Correlations among Technical Attributes: the Roof of the HoQ

Having arrived at a validation of an apple experiment's contribution to fruit consumption, it is hard to imagine that one's focus does not shift towards the perspective of further consumer-driven quality improvement and new-product development. One of the questions then becomes which combination of values of the technical attributes would increase the likelihood of consumption even more. To investigate the different possibilities within the scope of the experiment, it is then worth to have a look at the roof of the HoQ. Here, positive and negative correlations between technical attributes are presented. By consulting this information, we realize that the apple is not decomposable in independently manipulable technical attributes, which can (within the scope of an experiment) be combined in whatever way that would be desirable for meeting consumer demands. For example, in an experiment on the effects of 1-MCP on quality parameters in apples ('Golden Delicious'), the value of ground colour is positively related to the amount of acidity, as by 1-MCP, better retention of acidity and of a high ground colour value (green), both fruit quality parameters for storage, are observed. Thus, it will be impossible to maintain the same acidity amount and simultaneously change the ground colour (to more yellowish) by applying 1-MCP if consumers wished this. As such, directions for new experiments should find a balance between meeting consumer demands and technical feasibility.

In addition to the fact that the apple is not decomposable into separately manipulable attributes due to technical correlations, one has to be aware that these technical correlations depend specifically on the technical experiments which are applied to influence technical attributes. For example, in the 1-MCP experiment, the ground colour level and the acidity amount are related positively, whereas in a Hot Water Treatment experiment, the ground colour level and the acidity amount do not correlate. By Hot Water Treatment, the ground colour value of Golden Delicious may be lower, i.e., less green, while the acidity level remains unchanged. Consequently, from the perspective of a single technical experiment, information about technical correlations cannot be provided in one and the same roof of the ISAFRUIT HoQ, as the original concept of the HoQ suggests. Instead, different experiment-/technology-specific roofs will have to be considered.

DISCUSSION

Bringing the ISAFRUIT HoQ to the point at which it is now was not always an easy process. First of all, there were some difficulties because technical and consumer scientists attached different meanings to the same term (e.g., variety) as explained before. Also with respect to, for example, “crunchiness” (firmness of flesh vs. firmness of peel); consumers have different sensory connotations with “crunchiness”, such as the sound when biting an apple (auditive), whereas technical scientists collect data about the firmness of the flesh of an apple by measuring its mass (kg/cm^2). In general, the terms that consumers use tend to be relatively vague and to vary across consumers, which makes it difficult to arrive at a conclusive list of relevant consumer-demand related attributes and difficult to characterize their link to technical attributes. Consumers, while expressing themselves, simply do not stick to scientific terms and definitions. It seems that consumer-demand related attributes for fruit, e.g., fruity taste, are more difficult to articulate than that for cars, e.g., fast acceleration. What exactly does the consumer mean with “fruity taste”? Should it be sweet, sour, somewhat bitter, or what? Quite a portion of reflection is necessary here in order to avoid indifference to demands consumers have. Sensory language might capture the consumer language better as sensory related terms are very specific and consummation oriented compared to technical terms which focus on technical processes.

The consumer perception of “healthy” also need not correspond with technical assessments of “healthy”, e.g., consumer’s estimate orange juice as most healthy, but on the technical side, it is known that orange juice can contain high levels of pesticides and often contains too much additional sugar. This fact shows that consumers are not always well informed, but rather make decisions based on wrong knowledge. Here, technical consequences regarding higher production of orange juice may be ignoring the fact that consumers actually need to consume orange juice containing less pesticides in order to consume healthier. On the other hand, the ISAFRUIT strategic objective says “increase fruit consumption, searching for the improvement of health and well-being of Europeans and their environment”, and it is not necessarily most effective to convince consumers to consume the healthiest fruit, as the health effect of “a larger portion of less-healthy fruits” can be larger than that of “a smaller portion of healthiest fruits”. Also, it is not about increasing the consumption of one kind of fruit at the expense of the consumption of other kinds of fruits. Nor is it about convincing consumers to consume fruit beyond what is seen as a normal weight.

Although a lot of effort has been put in the current ISAFRUIT HoQ, it should not be considered as the *final* version. On the contrary, inclusion of additional technical experiments may necessitate the inclusion of more technical attributes. Additional consumer research (in different countries and in a few years time) may: *i*) reveal different consumer segments with associated importances and perceptions, *ii*) quantify the importances of those consumer-demand related attributes that were not included in the ISAFRUIT consumer survey, *iii*) shed more (or different) light on the character of the linkages, and *iv*) give information about the perception of other competitive food products in comparison to apples. Nevertheless, the current ISAFRUIT HoQ can be considered as a valuable starting point for systematically validating apple experiments from the perspective of increasing fruit consumption. From our experiences in building it, we can say that it seems imperative that such efforts to extend and apply the

ISAFRUIT HoQ are always undertaken by interdisciplinary teams.

When it comes to the roof, it should be kept in mind that the correlations among technical attributes in one area of technology development may not necessarily apply to another area of technology development. The roof is only fixed given available competencies and assets, but existing correlations may be alleviated and unrelated technical attributes may become correlated under different conditions.

Needless to say that this validation can only be preliminary and that further steps in the so-called innovation funnel such as concept testing and a test market should be taken to get stronger validation results. Nevertheless, the ISAFRUIT HoQ can be used in case the resources for such further validation steps are not available.

The ISAFRUIT HoQ can be also considered as a starting point for a HoQ that serves different goals than the one we had in mind, e.g., for scientific project managers to discover strategic opportunities for other apple experiments, HoQ's for other fruits, and directions for new research projects in general aiming to increase fruit consumption, for marketers, and for policy makers. Each of those goals, however, will require contextual tuning and, therefore, substantial modifications of the HoQ.

CONCLUSIONS

The HoQ and the TEA House provide a tool to systematically evaluate apple experiments from the perspective of their likely contribution to increased fruit consumption. Building the tool requires a lot of effort from, and interaction between, technical and consumer scientists. In the building process, both 'hard' directly traceable empirical evidence and 'soft' expert knowledge are included. Working with such a complex and encompassing tool requires, on one hand, a lot of effort from the involved stakeholders in order to understand the complexity of the tool, and also the complexity of reality itself (different cultivars and different experimental and non-experimental conditions entail varying results which are difficult to incorporate simultaneously into the HoQ; consumers differ both in the importance they attach to attributes and their perceptions of products), but, on the other side, increases the awareness and knowledge by increased structured communication, and fosters synergies and interaction. Finding and developing a common interdisciplinary language is necessary for successful interdisciplinary projects, which are more and more demanded in research. Additionally, in the process of creating a common language and shared understanding added value evolves, and research becomes more understandable by external stakeholders like policymakers and consumers (Bertschinger et al., 2009).

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Application of Consumer and Sensory Research in the House of Quality
Case Study: CASA Sprayer - Crop Adapted Spray Application

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Abstract

In apple production, fungicides and insecticides are used both pre- and post harvest to protect the apples from a range of pests and diseases and to provide quality preservation. Within the ISAFRUIT Project, a Crop Adapted Spray Application (CASA) system was developed to ensure precise, efficient, and safe spray applications in orchards, according to the actual needs of the crop and with respect for the environment. The CASA sprayer is a major and important technical development. However, as it is mainly an improvement for the grower segment of the fruit chain, the impact on the consumer demand related attributes is probably less direct. The impact on consumer-demand related attributes, according the House-of-Quality (HoQ) is described and discussed.

INTRODUCTION

In apple production fungicides and insecticides are used both pre- and postharvest to protect the apples from a range of pests and diseases and to provide quality preservation. Due to the potential risk of pesticide residues to human health, the use of pesticides is strictly regulated e.g., by the Maximum Residue Level (MRL). MRLs are specified for each active ingredient and represent the levels admitted on fruit post-harvest. Many countries have monitoring programmes for pesticide residues in food to ensure that they do not exceed the MRLs. These monitoring programmes have shown that fungicides and insecticides are often found in apples (EFSA, 2009).

Pesticide residues per fruit weight unit are dependent on three factors: variation in initial spray deposit, physical decay due to weather factors and growth dilution. Variability in residues between individual samples is inevitable, partly because it is difficult to achieve a uniform spray deposition of pesticides. Application technique, crop architecture and growth stage have all been shown to affect variability in initial deposit. One of the most important factors influencing pesticide residues is the canopy structure. Many studies showed the importance of canopy structure in affecting initial deposit concentrations (Xu et al., 2006; Rawn et al., 2007); usually fruit in the top and outside regions of the canopy are likely to receive more deposits than those inside the canopy. Also, in many practical situations the initial deposit is influenced by spray technology (i.e., sprayer type, sprayer settings and nozzle type). Large variability in the level of residues exists between individual sample units and composite samples. There are internationally agreed standards for monitoring pesticide residues and for assessing risks of consumer exposure.

Within the ISAFRUIT Project, a Crop Adapted Spray Application (CASA) system was developed to ensure precise, efficient, and safe spray applications in orchards, according to the actual needs of the crop and with respect for the environment. The system consists of three sub-systems: *i*) a Crop Health Sensor (CHS), identifying the health status of the fruit trees; *ii*) a Crop Identification System (CIS), identifying tree canopy size and density; and *iii*) an Environmentally Dependent Application System (EDAS), identifying environmental circumstances during spray applications (Balsari et al., 2008; Doruchowski et al., 2009; Van de Zande et al., 2007; Zande et al., 2009).

The complete system minimizes spray drift by nozzle size (droplet size) selection and air support settings, and by the use of ultrasonic sensors that recognize the shape of the trees, thereby adapting spray volume to tree canopy volume, and ultimately a sensor that can recognize a disease. Altogether, it should minimize the use of plant protection product (PPP) and therefore residues on fruit.

In this paper the results of experiments with the CASA sprayer are summarised and evaluated in respect to consumer demands. Consequences of the use of the CASA sprayer for consumer demand related attributes are described and discussed.

Fig. 1. CASA-sprayer.

External Damage of Apples

The sprayer prototype equipped with the Crop Identification System (CIS) was tested in a Gala apple orchard in Italy. During the growing season 10 spray applications were made using 10 different pesticides. Assessments of biological efficacy of pesticide applications were made for important pests and diseases that cause external damage of the fruits; i.e., apple scab (*Venturia inaequalis*), powdery mildew (*Podosphaera leucotricha*) and green apple aphids (*Aphis pomi*).

Residues on Fruit

In a field trial, the effect of droplet size (nozzle type – an important factor in spray drift reduction) on residues on apples was evaluated in a commercial orchard. The spray applications for the reference situation were performed with standard hollow cone nozzles (fine spray) and for the low-drift situation with air induction hollow cone nozzles (coarse spray). The orchard was divided in two experimental plots. Each plot was sprayed for the whole season with one (the same) nozzle type, according to a standard commercial spraying scheme with insecticides and fungicides, following label directions. Total residue levels (e.g., captan, bupirimate, pyraclostrobin and boscalid) per fruit and residue concentrations (mg kg^{-1}) at harvest were determined according to standard analyzing procedures and methods, and expressed for individual fruits (Wenneker et al., 2009; Poulsen et al., in preparation).

EFFECTS ON APPLE QUALITY TECHNICAL ATTRIBUTES

External Damages

The assessments revealed that the incidence of apple scab and of powdery mildew on leaves, observed at the end of June, were very low and resulted in no statistical difference between the standard method and the CIS-system. Similar results were observed for the green apple aphid. At harvest time, damage on fruits due to apple scab and to powdery mildew was very low and no significant differences were observed between the treatments examined. These results show that the CIS sprayer prototype with the ultrasonic sensors switched on, which adapts the spray volume (and consequently the pesticide doses sprayed per hectare) to the vegetation development, enables to obtain the same biological efficacy, and hence, the same quality of fruit, as standard spraying systems. Moreover, sensors on the sprayer revealed that the overall amount of pesticides was reduced by about 33% during the season.

Pesticide Residues

The mean residue levels in apples for the coarse and fine droplet applications did not differ significantly. However, large variations in residue levels were observed between the individual apples, either sprayed with coarse or fine droplets. These large variations were also present between fruit within the different zones. Apples from the middle or lower outside position showed the highest residue levels. The results indicated that the residue levels appeared to be independent of fruit size or weight.

The Crop Identification System (CIS) mounted on the sprayer prototype, even if applying a reduced volume rate (and therefore a reduced PPP dose), was able to provide a better quality of spray distribution on the target, both in terms of spray deposits and evenness of spray deposition, compared to the conventional application method.

The combination of CIS with a coarse droplet nozzle is expected to reduce the pesticide dose sprayed, improve the distribution, and reduce the variation of pesticide residues between individual apples. Eventually, this should result in fruit with lower residue content overall, and less individual fruit with high residue levels. This is the focus of the trials performed in 2010.

Prices and Costs

Roelofs and Groot (2012) made an economic evaluation of new innovative techniques. Use of the CASA sprayer leads to lower costs for the grower and therefore higher returns. This means that fruit growers might be willing to invest in this technology. However, as it only shows small differences, it is still important to keep the costs in mind.

Yield Class 1

If the CASA sprayer leads to lower damages by pests and diseases, the amount of class 1 production would increase.

IMPACT ON CONSUMER-DEMAND RELATED ATTRIBUTES

Apples grown in Europe are susceptible to a wide range of pests and diseases. The high demands of consumers for quality fruit cannot be met unless these pests and diseases are adequately controlled. The use of pesticides is often inevitable. However, pesticides are regarded as highly undesirable by consumers. The CASA sprayer allows less chemical input for the same results on crop protection. This means that the CASA sprayer has an effect on two important technical attributes: the amount of residues and external damages. Beside these, also costs and yield of class 1 fruit are influenced. The changes in technical attributes have the following consequences for consumer demand-related attributes:

- ✓ Taste: no real impact.
- ✓ Texture: impact on this attribute is unknown or indifferent.
- ✓ Smell: will be better, due to less external damages.
- ✓ Appearance: will be better due to less external damages.
- ✓ Promote health and well-being: will be better, due to less residues and less external damages.
- ✓ Safe: a lower amount of residues leads to a higher feeling of safety by consumers; however, the House of Quality gives also positive relationship between the amount of external damages and safe, which means less external damages, less safe. This seems contradictory.
- ✓ Convenience: overall the convenience, with aspects like easy and quick preparation and consumption, availability, easy storage and transport as well as clean consumption, will be improved. However, it might be negatively influenced due to lower availability and/or more difficulties in storage.
- ✓ Price: might be positive, when there is a clear relationship between production costs and consumer price, as it seems that use of the CASA sprayer leads to lower costs for the fruit grower. However, this relationship is not that direct and costs for fruit growers are not mentioned in the HoQ. Therefore, no real impact on consumer price is likely.
- ✓ Pleasant association: less residues as well as less external damages lead to a more pleasant association with fruit. It is more appealing to eat an apple without damages.
- ✓ Product differentiation: the effects of these technical attributes are mostly indifferent.
- ✓ Production: aspects as low environmental impact are positively influenced when using fewer chemicals.

DISCUSSION

The CASA sprayer is a major and important technical development. However, as it is mainly an improvement for the grower segment of the fruit chain, the impact on the consumer demand related attributes is probably less direct. Mainly the attribute "promote health and well-being" is influenced positively. Other positive effects are based on the assumption that using the CASA sprayer leads to less external damages, which is not that clear. The only technical results are that there is no statistical difference between the results of the standard way of crop protection and the CASA sprayer, despite a reduction in chemicals applied. Convenience, an important consumer attribute, will be mainly improved, but could be influenced negatively due to a possibly lower availability. Perhaps the HoQ should be extended to include a process of weighting of the different consumer related attributes. For example, has the attribute smell the same importance as promoting health and well-being?

The effect of the CASA sprayer on internal damages is not clear. At the moment, it is proven statistically that the CASA sprayer leads to the same results on crop protection as the standard spray applications. Perhaps with further development of the crop health sensor, both internal and external damages could be reduced. This would positively influence consumer attributes.

Also, more environmentally-safe production seems an important attribute for consumers, as the protection of the environment is of increasing public concern. The CASA sprayer causes a reduction of chemical residues in fruit and minimises the environmental impact of agrochemical application by precision dosing and crop oriented application of chemicals, thereby contributing to sustainable production of safe and healthy fruit.

RECOMMENDATIONS

Costs for fruit production are missing as technical attribute in the ISAFRUIT HoQ.

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Application of Consumer and Sensory Research in the House of Quality
Case Study: Shading for Thinning

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Abstract

One line of research in ISAFRUIT dealt with testing the application of shade as an effective thinning method to substitute chemical thinning. This work was carried out in two different European locations, which allowed to test for environment-related variations in the response. Over three growing seasons the method proved to be effective and the results repeatable. The fruit obtained from this thinning method were of quality comparable to those from the chemically thinned trees that represented the best practice control. The fact that the same results were obtained by a more sustainable method that uses no chemicals, is the most relevant factor of this approach. Several consumer-relevant traits indicated in the WALL of the House of Quality are influenced by this method, and the fact that it does not cause a loss from the standard, and in some cases it induces even better results, confirms its viability. However, this method is considerably more expensive than chemical thinning, and could today only be recommended for organic growers who do not want to use mechanical thinners. Further work is needed to reduce this considerable hindrance.

INTRODUCTION

To be economically successful apple growers must manage two conflicting goals: producing fruit of the maximum quality (in terms of size, sweetness, firmness, acidity, juiciness), while retaining the highest possible yields. This balancing act requires accurate management of the number of fruit on a tree (crop load): excessively low crop loads lead to reduced productivity, despite larger fruit; too many fruit, on the other hand, will increase yield per tree and per hectare to the detriment of fruit size. To make matters worse, excessive crop loads cause many apple cultivars to bear only in alternate years (Jimenez and Diaz, 2004). Growers control crop load, mostly after fruit set has occurred, by removing fruit (thinning) to reduce that number to 10-20% of the initial fruitlet population, aiming for the optimum level determined for each tree and cultivar. Thinning is therefore one of the most important orchard management techniques used to improve crop yield and quality in apple (Link, 2000; Byers, 2003).

Growers can apply various management techniques to reduce crop load. Hand removal is possible but excessively expensive in most cases. Chemicals normally are applied that cause fruitlet abscission, but their efficacy is not always satisfactory, since they can be affected by many, not well understood factors, such as weather conditions at the time of application. In addition, the use of these chemicals is restricted by safety legislation that varies in different European countries and companies must undergo time-consuming and expensive procedures to have new molecules approved. The problem is even worse in organic growing, where chemical thinning is not allowed and growers are restricted to solutions either very expensive (hand-thinning) or that often are not very effective, with serious consequences on fruit quality, yield and income for the growers.

Inhibiting photosynthesis of the apple tree by heavy shade post-bloom is known to cause fruit drop, although its use in commercial orchards has never been attempted because of several – yet unsolved – technical considerations: cost, difficulty in determining when and how long to apply the shade, cultivar-specific response, etc. However, if successful, this approach offers the possibility to achieve the same result as chemical thinning, but with reduced impact on the environment, and reduced amount of chemicals sprayed on the fruit, which are perceived as desirable features.

Within ISAFRUIT, two research teams have worked to improve the scientific knowledge on how different environments affect the response of the tree, the response of different cultivars, and to devise a method to decide when to remove the shading material, in order to avoid over-thinning, with the goal of bringing this crop control method closer to potential adoption by growers. The teams are located in Wadenswil, Switzerland and Bologna, Italy.

Wadenswil and Bologna have quite different environments, from alpine to low-land; this induces widely different degrees of vigor in the trees, even if they belong to the same cultivar. These two different locations allowed testing the effect of environment on the same cultivar (‘Golden Delicious’), and provided information on additional cultivars that are differentially grown in the two districts. Although variations were carried out over the years in both locations, the trials tested the general idea whether thinning can be achieved with an efficacy comparable to that afforded by chemical thinning, which is considered as the industry standard.

METHODOLOGY OF THE STUDIES

The experimental set-up was quite different between the two locations and the years, but in essence the trials consisted of placing a very strong shading (70-90% shade) material on trees of the selected cultivars, at various times within 1 month after bloom (Fig. 1). In Bologna, where studies of this kind have been conducted over the last twenty years (Corelli Grappadelli et al., 1990, 1994; Tustin et al., 1992), an empirical method had been previously worked out to determine how long to shade to be effective, but not to over-thin (Musacchi and Corelli Grappadelli, 1994). This consists of monitoring daily the amount of abscissed fruit, in order to detect the sudden increase in fruit drop rate that in this environment has been found to signal the beginning of heavy fruit drop, at which time the shade must be removed. Though effective in Bologna, this approach caused excessive fruit drop in Wadenswil, where the necessary length of shading has been found to be about half of that in Bologna. As a result, in Wadenswil the duration of shading has thereafter been set to a fixed number of days (variable for different cultivars), which has been shown to work very well. The work has been repeated in different years to confirm the results. In Wadenswil, work has also been conducted to develop a mechanical solution to the problem of deploying/withdrawing the shading material, which remains one of the more urgent aspects to be solved before the attempt can be made of trying commercial implementation of the method.

Fig. 1. Experimental plot with shading nets of two lengths, 3 m (on the left) and 2 m (on the right) placed on trees in Wadenswil, CH.

Following shade application, several parameters were collected, both physiological and related to the quality of fruit. In this paper, reference is only made to fruit drop and the quality parameters of the product. For more specific information the reader is referred to Zibordi et al. (2009) and Zibordi (2010) for Bologna, and to Kockerols et al. (2010, 2011) for the Wadenswil results.

EFFECTS ON APPLE QUALITY ATTRIBUTES

The technical traits are listed in the CEILING of the House of Quality (see: Van der Lans, this volume). These are grouped in broad categories. Almost each of these broad categories contains one or more trait affected by the work described here: fruit size, sugar level, firmness, acidity, ground and blush color have all been measured and reported in the Swiss and Italian studies. It is important to underscore that the line of research pursued by these two teams aims at realizing an alternative approach to chemical thinning, which is thus assumed as the standard to which to compare the results obtained. Since crop load adjustment impacts all these traits, the fact that they were always at least comparable to the chemically-thinned controls, if not improved, means that this approach to crop control does not present negative aspects in these regards. As an example, the data from the Bologna 2007 study are reported in Table 1.

While fruit weight and diameter were comparable, fruit from the shaded trees had higher sugar content, acidity and flesh firmness. Similar data were found in the Swiss trials in the years of testing. A similar remark can be made in relation to the economic trait, yield of Class 1 fruit: in the Bologna trial in 2007 the amount of fruit per tree (crop load) and fruit weight were similar for the two treatments.

The work carried out over the years in the two locations has shown a high degree of agreement in the results. On several cultivars it was shown that shading can thin the fruit to an extent similar to the industry standard, yielding commercially quite acceptable fruit at satisfactory yield/ha levels. The Bologna "dynamic" method to decide the length of shading was effective in 2007 (Fig. 1), while the "static" approach (a fixed length at predetermined times) was effective in Wadenswil over two growing seasons and three cultivars (Fig. 2). The 2008 study in Bologna (Zibordi, 2010) showed a linear relationship between the loss of carbon (estimated via a carbon-balance model) and the amount of fruit drop. This is encouraging as the existence of linear relationships of this kind might allow to base the decision to remove the shade cloth upon current-season conditions, in real time (Zibordi, 2010).

The economics of shading net as an alternative to chemical thinning were assessed by the Swiss team. Their analysis showed that, while still much more expensive than chemical thinning, shading might already be viable in an organic orchard, if this were hand-thinned. Currently, testing is under way to assess machine thinning, which looks quite promising. If this solution were successful, then it might make shading completely uneconomic, because it could be applied to organic as well as integrated orchards for a fraction of the cost of shading, although other considerations might become relevant, as the level of tree damage created by the mechanical thinners.

IMPACT ON CONSUMER-DEMAND RELATED ATTRIBUTES

The ISAFRUIT House of Quality in the WALL lists Personal and Societal consumer-related attributes. In the former, fruit attributes (taste, firmness, juiciness, smell, appearance, etc.) are associated to consumer perceptions of fruit (promotion of health and well being, pleasure, convenience); in the latter, low environmental impact and fair trade are included. Many of the Personal consumer-related attributes are related to the technical attributes described above. Crop load adjustment has an effect on fruit taste, firmness, sugar levels, size, etc. The relationships between these consumer-related attributes and the technical ones are described in the "ROOMS" linkage matrix.

Table 1. Effects of shading (90%) and chemical thinning on final production and quality of 'Imperial Gala' apples.

Thinning treatment	*Crop load (fruit cm^{-2})*	*Yield efficiency (kg cm^{-2})*	*Fruit weight (g)*	*Diameter (mm)*	*Sugar content (° Brix)*	*Flesh firmness (N)*	*Titrable acidity (g l^{-1})*	*Background colour (h°)*	*Blush colour (h°)*
Chemical	4.17	0.58	164.9	73.0	12.9	67.5	2.85	93.6	29.3
Shade	4.08	0.6	165.4	72.3	13.1	71.2	3.43	95.5	31.9
	ns†	ns	ns	ns	*	**	**	ns	*

†ns, *, **: not significant, or significant at P≤0.05 or P≤0.01, respectively.

Providing an alternative management tool that does not reduce the quality standards afforded by the current best practices while maintaining yields can be considered successful. This tool has the additional benefit of reducing the level of chemicals employed in apple production – since no chemical thinners are employed here. This addresses the Societal consumer-related aspect of low environmental impact.

DISCUSSION

Although the work carried out in the trials described here had not been planned with the benefit of knowledge of the ROOM linkage matrix of the House of Quality, it lends itself to an analysis according to this method. The consumer related traits of taste, texture, appearance are very sensitive to the growth pattern of the fruit, which in turn responds to tree crop load. When trees are properly thinned, cell division is promoted; with more cells, the fruit has a greater potential to achieve optimum quality. Removing competitor fruit makes it possible for the survivors to achieve that potential. The end product is a fruit of larger size, more sugar and acidity, with firmer flesh and better blush color. This is normally achieved with thinning. This work aims at improving the sustainability of fruit growing by applying an effective thinning method that does not require application of chemicals. This "environmentally friendly" trait adds to the capacity of this method to address consumer-relevant traits.

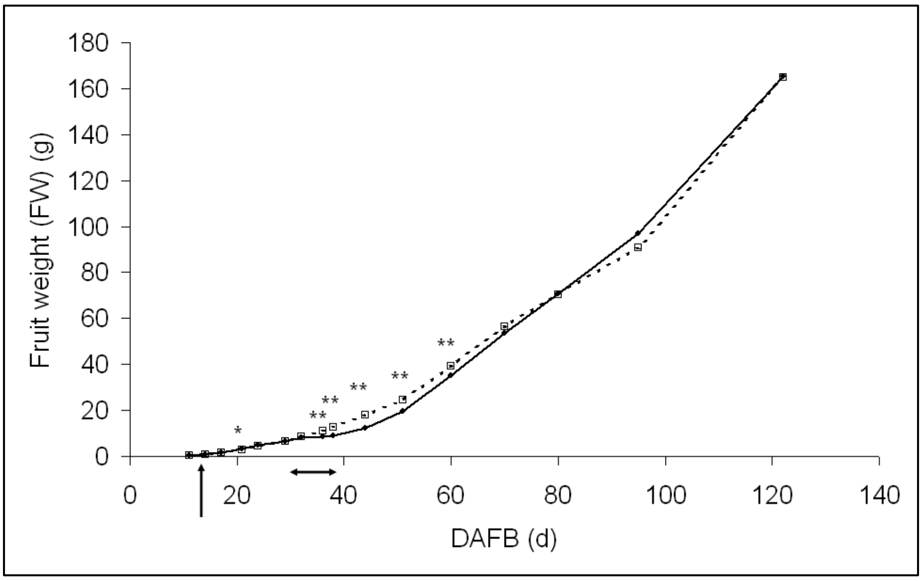

Fig. 2. Bologna, 2007 study. Fresh weight (FW) of fruit growing on chemically-thinned (open squares, dashed line) trees or trees thinned by shading (black dots, solid line). The vertical arrow indicates the date of chemical thinning. The horizontal arrow indicates the start and end of shading.

**, **, significant difference at P≤0.05, or P≤0.01, respectively.*

On the down side, fruit price is one of the Personal consumer-related traits that are present in the WALL of the House of Quality, and the high cost of this method cannot and must not be overlooked, if it is to become adopted in the future. However, the relationship between cost of production (which is impacted by adoption of this tool) and consumer price is not defined in the current HoQ, and it is not clear how much in reality the latter depends on the former. It is a common observation that price to the consumer is 3-4 times higher (and can be more) than price paid to the producer, therefore it can be surmised that the relevance of a higher cost of production for the consumer-related aspect of price would be of a relative impact.

CONCLUSIONS

The thinning-via-shading method that has been tested in Bologna and Wadenswil has the potential to be adopted commercially, following protocols that have been defined/refined during the ISAFRUIT Project. This method has repeatedly proven to be fully comparable, in terms of quality of fruit and yield, to the industry standard of chemical thinning (followed by hand-refinement), which was the goal of the research, whose merit is that it reaches its goal without application of chemicals. The aspect of high costs still is unsolved, and further research is needed to address this aspect, as is the solution to an objective method to decide when to remove the shading material. However, the search for a solution should be encouraged by the awareness that it is more sustainable and capable of impacting consumer-important attributes than currently adopted methods.

RECOMMENDATIONS

As indicated above, this work was planned before the results from the consumer surveys were available, and it can be said that these results would have probably placed this work in a more prominent position within ISAFRUIT Pillar 5. When it was decided to include this work, in fact, the rationale was that of pursuing greater sustainability of fruit growing, i.e., realising only one of the consumer-relevant traits that are now included in the House of Quality. It could be said that the research was planned and placed in the right context by serendipitous luck, while it could have availed itself of this knowledge, had it been at hand.

That fruit obtained with this thinning method do not lose in quality, while being produced with a more sustainable method can arguably be regarded as a result “in line” with the goal of ISAFRUIT of improving fruit consumption. However, cost considerations apart, consumers will need to be quite well informed that such an environmentally friendly method was used. That is, altogether, a challenge.

The availability of the House of Quality “ex-post” makes it difficult to say how different the technical experiments would have been, had it been available “ex-ante”, but it probably can be said that it would have provided a guide to better fit the technical side (e.g., by adding the measurement of consumer-relevant traits) to the consumer one. If consumer preferences were not too volatile the current House of Quality might be useful for future applications.

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Evaluation of Post-Harvest Treatment of Apples with Hot Water and GRAS Chemicals for Control of Fungal Rots in Store

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Abstract

Most apple cultivars are harvested between August and November. Cold storage of fruit is therefore essential to extend the marketing period and the availability of local fruit for consumers. Fungal rots can cause significant losses in store if appropriate control measures are not applied. In this paper the results of experiments with GRAS chemicals and hot water treatment (HWT) on control of fungal rots are summarised and evaluated with respect to consumer demands. Consequences of the use of GRAS chemicals and HWT on consumer demand related attributes are described and discussed.

INTRODUCTION

Most apple cultivars are harvested between August and November. Cold storage of fruit is therefore essential to extend the marketing period and the availability of fruit for consumers. Fungal rots can cause significant losses in store if appropriate control measures are not applied. In the UK, in the 1960s, up to 30% losses in stored 'Cox' apples due to *Gloeosporium* spp. was not uncommon (Preece, 1967). In more recent surveys from 2008 and 2009 (Berrie, 2010), average losses of 'Cox' apples caused by rots were around 1-3% but with losses in some orchards reaching over 10% mainly due to *Nectria galligena*.

Previously, in the UK and some other parts of Europe such as France, control of storage rots was achieved almost exclusively by the use of post-harvest fungicide treatments. Such treatments had clear advantages over pre-harvest sprays in that decisions on use could be delayed until harvest, when the risk of rots was known and the fungicide was targeted on the fruit only and not on the rest of the orchard environment. Though drenching fruit post-harvest was a very efficient method of applying fungicide, it also guaranteed a fungicide residue on the fruit which in general did not diminish in store.

Pesticide residues in produce are one of the key concerns for consumers. Today's consumers expect apples which are of high quality but also residue free. Any fungicide treatment aimed at controlling storage rots applied pre- or post-harvest are no longer acceptable because of the risk of residues in the fruit. Post-harvest fungicide treatment is no longer used and/or allowed on apples in many countries and much research in the last ten years has been devoted to developing an alternative strategy for rot control. Effective control of storage rots is dependent on a clear understanding of which fungal rots are important and their epidemiology.

Fungal rots can be classified into orchard diseases or store diseases. Orchard diseases originate from cankers, mummified fruit or soil splash and include brown rot (*Monilinia fructigena*), botrytis eye rot (*Botrytis cinerea*), *Phytophthora syringae*, *Nectria galligena* and *Gloeosporium* spp. These fungi infect fruit in the orchard between blossom and harvest, remain symptomless (or latent) and subsequently develop as rots in store. Store diseases originate from plant debris, dirty fruit bins or soil and include *Penicillium expansum*, *Mucor* spp. and *Botrytis cinerea*. These fungi rarely appear as rots in the orchard but generally infect fruit through wounds at harvest and develop as rots in store. Orchard and store rots by their nature require different approaches to control them. These control methods are summarised in Table 1.

Table 1. Control of storage rots.

Orchard diseases	*Store diseases*
Fungicide sprays at blossom and petal fall	Bin hygiene
Fungicide sprays pre-harvest	Selective picking of fruit at harvest (only undamaged fruit stored)
Hot water treatment to eliminate latent infections (e.g., *Nectria*, *Gloeosporium*) in fruit	Post-harvest treatment with GRAS* chemicals

* GRAS = Chemicals **G**enerally **R**egarded **A**s **S**afe

Work has been carried out as part of the European research project ISAFRUIT, to identify GRAS chemicals and hot water treatment regimes that could be used to control fungal rots in store and avoid the need for fungicide application near harvest.

In this paper the results of experiments with GRAS chemicals and hot water treatment (HWT) on control of fungal rots are summarised and evaluated with respect to consumer demands. Consequences of the use of GRAS chemicals and HWT on consumer demand related attributes are described and discussed.

Control of Store Diseases (Penicillium, Botrytis and Brown Rot)

Potential chemicals identified from previous research were tested in small scale experiments over two seasons. Products tested included sodium molybdate, chitosan (crushed crab shells), potassium bicarbonate, potassium metabisulphite, Jet 5 (peroxyacetic acid), vinegar (acetic acid), potassium sorbate, calcium chloride, sodium bicarbonate and Wetcit (alcohol ethoxylate). Chemical efficacy was tested against *B. cinerea*, *P. expansum* and *M. fructigena* using inoculated wounded apples of 'Cox' and 'Golden Delicious'. Chemicals were also tested against an orchard disease – *N. galligena* – using naturally infected 'Gala' apples. Separate experiments were done for each fungal rot and apple cultivar combination. 'Cox' and 'Gala' were treated in September and then cold-stored in controlled atmosphere (CA) until March. 'Golden Delicious' were treated in October and stored in air at 1-2°C until February. At the end of storage, the fruit was assessed and the number of infected wounds in the fruit recorded.

Of the chemicals evaluated in 2006, only sodium molybdate and Jet 5 showed reduction of infected wound sites, while sodium molybdate proved to be phytotoxic, with treatment resulting in brown patches on the apple skin. Changes in the permitted uses of Jet 5 (peroxyacetic acid) (EU Directive 91/414/EEC, commodity use expired on 31 December 2010) meant that it could no longer be used on food. Hence, in 2007, a range of new chemicals were evaluated. Most of the chemicals tested were ineffective. Only Chitoplant and Wetcit showed some control of botrytis and brown rot. Chitoplant contains chitosan, which, when applied to plants, stimulates improved resistance to disease. Wetcit is a natural wetter based on citrus extract.

Control of Latent Fungal Infection by HWT

Initial trials with HWT were aimed at identifying temperatures and dip times that eliminated latent fungal infections in fruit with minimal effect on fruit quality. Treatments were evaluated on the cultivars ‘Golden Delicious’, ‘Royal Gala’, ‘Braeburn’ and ‘Queen Cox’, at water temperatures of 50, 52, 54, 56, 58 and 60°C and with dipping times of 20, 40 or 60 seconds. ‘Royal Gala’ naturally infected with *Nectria galligena* (harvested from an orchard with a high incidence of canker) was also included to evaluate the efficacy of treatments in eliminating latent fungal infections. Treated fruit was cold-stored in controlled atmosphere appropriate for the apple cultivar. The fruit was assessed for symptoms of heat damage and fruit quality (firmness and colour) and the incidence of rots on removal from store in February to April 2008.

Cultivars varied in their tolerance to temperature and dipping time. Treatment at 52°C for 40 seconds was safe for all cultivars tested. Some cultivars could tolerate higher temperatures (up to 58°C) but with a shorter dipping time of 20 seconds. ‘Queen Cox’ was the least tolerant cultivar of higher temperatures. Higher treatment temperatures (58/60°C) and immersion periods of greater than 20 seconds tended to reduce firmness of ‘Cox’ and ‘Braeburn’ apples, whereas the firmness of ‘Royal Gala’ and ‘Golden Delicious’ apples was generally increased by HWT 52°C for 40 seconds was safe for all cultivars tested and had no adverse effects on firmness of any of the cultivars. The occurrence of skin damage limited the assessment of background colour to lower treatment temperatures. There was no effect of HWT on background colour of ‘Cox’ (50/56°C) or ‘Royal Gala’ (50/52°C) apples. However, HWT tended to increase yellowing in ‘Golden Delicious’ (50/54°C) and ‘Braeburn’ (50/58°C) apples. With the exception of ‘Cox’, there were few rots detected at the end of the storage period even in control fruit. However, treatment at all temperatures reduced rotting in ‘Cox’ compared with no treatment.

HWT was also evaluated in combination with GRAS treatments. ‘Royal Gala’, naturally infected with *N. galligena*, were hot water treated at 50 and 52°C for 20 or 60 seconds and then dipped in acetic acid, potassium sorbate, calcium chloride, chitosan, sodium bicarbonate or alcohol ethoxylate for one minute. Fruit was then cold-stored in CA and assessed for symptoms of heat damage, firmness, colour and incidence of rots in March 2008. Rotting (predominantly caused by *Nectria*) was reduced by HWT and tended to be reduced by GRAS treatments and particularly by alcohol ethoxylate

(Wetcit). The most effective combined treatment was HWT + alcohol ethoxylate (Wetcit).

Commercial Evaluation of Combined Treatments for Control of Orchard and Store Diseases in Orchard Trials

Trials were established in three ‘Cox’ orchards (all with low to moderate incidence of canker) at East Malling Research Centre in 2008 to compare early season fungicide treatments (captan or pyraclostrobin and boscalid) for control of *Nectria* rot and selective picking at harvest (to reduce store diseases) with post-harvest HWT (52°C for 40 sec) and GRAS chemicals (Wetcit) for control of orchard and store diseases. Fungicide treatments were applied twice – at late blossom and 10-14 days later. The orchards received a standard fungicide programme for control of apple scab and mildew and for nutrients, especially calcium. Fruit was harvested at the optimum time for long term storage. HWT was applied to boxes of apples which were then transferred to bins for storage. Wetcit was applied to bins of apples as a post-harvest drench using a Hudson commercial drencher. The fruit was cold-stored in CA until February where the incidence of rotting was assessed.

Most of the rotting was due to *Colletotrichum* spp. (latent infection) which was reduced by the early fungicide programme and HWT. The incidence of *Nectria* rot was very low. The incidence of the store diseases (*Penicillium* and *Botrytis*), which may have been controlled by post-harvest treatment with Wetcit or selective picking, was too low to draw any conclusions.

IMPACT ON CONSUMER-DEMAND RELATED ATTRIBUTES

The high demands of consumers for quality fruit as well as for low residue levels induced the search for alternatives for chemical treatments against fungal rots. HWT and GRAS chemicals offer such a solution. With these treatments, pesticide residues are minimized. However, HWT can affect technical attributes such as “internal damage” “ground colour” and fruit “firmness”. These changes in technical attributes have the following consequences for consumer demand-related attributes:

- Taste: less “internal damage” has a positive effect on the attribute “good taste”. However, if “firmness” is reduced, this will have a negative effect on the “good taste” as well as on “constant over time/homogenous” taste.
- Texture: impact is contradictory. Lower “firmness” leads to poor “texture”, less internal damage leads to better “texture”.
- Smell: indifferent impact.
- Appearance: might be slightly negative due to lower “firmness” and poor “colour” which leads to less “homogeneous” appearance.
- Promotes health and well-being: this attribute will be slightly improved, due to less “internal damage”.
- Safe: no clear impact. “Ground colour” and “firmness” have an indifferent relationship with this attribute. “Internal damages” has a positive relationship with the safety aspects “low pesticides/chemicals” and “no ‘dangerous’ technology”.
- Convenience: this might be positive due to less “internal damage”.

- Price: indifferent impact.
- Pleasant associations: less “residues” as well as less “external damage” lead to a more pleasant association with fruit. It is more appealing to eat an apple without damage.
- Product differentiation: the effects of the technical attributes are mostly indifferent.
- Production: aspects such as “low environmental impact” are positively influenced when using fewer chemicals.

DISCUSSION AND CONCLUSIONS

Failure to control storage rots, particularly latent infections such as *Nectria* and *Gloeosporium*, can have a significant effect on the profitability of apple production as the incidence of these rots increases the longer the fruit is stored. Such rots can also continue to develop after the fruit is marketed and affect the consumers’ acceptability of the product. Therefore, any control measures applied must be reasonably effective.

Fungicides applied pre- or post-harvest are the most effective means of controlling these rots with minimal impact on fruit quality attributes such as firmness, colour and taste. However, use of fungicides near harvest guarantees the presence of a fungicide residue in the fruit and this has a negative impact on consumer demand related attributes. The HWT and GRAS chemicals evaluated here offer alternative means of controlling latent fungal rots and wound rots without fungicide residues.

In the UK, *Nectria* rot is the most important latent rot in stored apples, while the incidence of *Gloeosporium* rots is most important in other parts of Europe. Recent research has demonstrated that much of the rot that develops in store results from infection of fruit in late blossom and petal fall (Xu and Robinson, 2010). Fungicide treatments applied at this time were effective in reducing the incidence of *Nectria* rot in store. Applying fungicides early in the season for control of storage rots has many advantages, particularly minimising the risk of residues in the fruit at harvest and also having no impact on fruit quality. *Colletotrichum* rot may also be reduced by fungicides applied at this time. HWT reduced the incidence of *Nectria* rot in store but has the risk of causing adverse effects on technical fruit quality attributes such as firmness and colour.

Gloeosporium spp. is generally controlled by use of pre-harvest fungicide sprays. The trials summarised in this paper have demonstrated HWT to be an effective alternative means of controlling this rot. However, possible negative side-effects on technical fruit quality attributes such as firmness and colour could have a major impact on shelf life and consumer acceptability.

The impact on consumer-demand attributes as shown by the ISAFRUIT House of Quality (HoQ) is indifferent. A decreasing firmness due to the HWT has a negative effect on consumer attributes like taste, texture and appearance. It is up to the consumer if this is compensated for by the positive effects of the attributes convenience and low environmental impact due to lowered use of chemicals.

HWT is a more labour and energy intensive technology compared to spraying with chemicals against fungal rots. Increases in labour and energy consumption will lead to an increase in costs for the growers. Higher costs do not necessarily lead to higher consumer prices. The link between production costs and consumer prices is not clear at all and it would be worthwhile to investigate this further, and then to incorporate the findings into the ISAFRUIT HoQ.

Very few of the GRAS chemicals evaluated are effective in controlling storage-related diseases. Wetcit, which is a natural wetter based on citrus extract, was shown to be effective in reducing *Penicillium* and brown rot.

The consumer-demand attribute ‘safe’ is difficult to interpret. If there is a positive relationship between internal damages and the safety aspect “no ‘dangerous’ technology” as stated in the ISAFRUIT HoQ (REF, see van der Lans, this volume), this would mean less damage, less “no ‘dangerous’ technology” which again means less safe. This seems illogical.

The ISAFRUIT HoQ currently provides no possibility of establishing the relationships between the use of GRAS chemicals and consumer attributes, as a technical attribute as use of non-chemicals is missing, but it can be assumed that consumers prefer the use of GRAS chemicals to conventional fungicides. GRAS chemicals are only effective against wound pathogens such as *Penicillium* and *Botrytis*. These pathogens require wounds to gain entry to fruit. An alternative approach to the use of GRAS chemicals is careful harvesting of the fruit to avoid damage. This combined with the use of clean fruit bins has been shown to reduce the incidence of wound rots (Colgan and Johnson, 1998).

This paper shows that the House of Quality is a way of interpreting technical aspects of research in a consumers’ way. The House of Quality is not yet completed. In some way it seems illogical. However, it shows that what seems only positive in a technical point of view, in a consumers’ view can be both positive and/or negative. As the competitiveness of the fruit industry depends on the consumers’ view, it is worthwhile that the House of Quality should be thought out in depth, both in structure as well as in relationships between technical aspects and consumer aspects. Finally: this House of Quality is made for apples, for other fruit species relationships can be different and should also be thought of.

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Application of the House of Quality
Case Study: Consumer Oriented Product Development of Dried Fruit

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Abstract

Dried fruit is a promising product in the drive to increase fruit consumption. Within ISAFRUIT, dried fruit has been studied from different perspectives, e.g., by consumer, sensory and technology scientists. In this study those data from different disciplines are integrated into the ISAFRUIT House of Quality (HoQ), a helpful tool in product development. The aim of this paper is to describe and reflect on the application of the HoQ for dried fruit. Therefore, the results obtained in previous work within ISAFRUIT both on the consumer and technology side are used. Although data limitations prevented the full exploration of the method, it was still a very useful tool for structuring and organising the multidisciplinary results from consumer perspective.

INTRODUCTION

As part of a drive to increase fruit consumption, dried fruit shows potential as it is a food product which combines healthiness and convenience. Therefore, the ISAFRUIT project has investigated technological properties as well as consumers' perception and sensory evaluation of dried fruit. Having so diverse data available is a unique opportunity to apply them in the process of designing and creating new fruit products and integrating technological and consumer perspectives. One of the most important success factors, during the process of developing and launching a new product is to take into account the voice of the consumer (Van Trijp and Steenkamp, 1998). The Quality Function Deployment method (QFD), more specifically the House of Quality (HoQ), is an interesting tool to structure the process of linking consumer demands and product characteristics. Due to confidentiality of data, only few practical applications of the HoQ in the food domain are available in the literature (Costa et al., 2000; Benner et al., 2003). Thus, the aim of this paper is to describe and reflect on the applicability of the HoQ to the example of dried fruit products developed within the ISAFRUIT project.

MATERIALS AND METHODS

A selection of the results of qualitative and quantitative consumer research, as well as sensory research and experimental technological research on dried fruit have been used in the paper. All data presented are derived from the ISAFRUIT Project Work Packages (WP) 'INNOFRUIT' (Innovations in the European Fruit Industry, WP 1.3) and 'DRYFRUIT' (Dried Fruit, WP 3.3). (See Table 1 for an overview). The results used for each of the rooms of the HoQ will be referred subsequently.

House of Quality for Dried Fruits

The data on dried fruit gathered within ISAFRUIT seem to be sufficient for constructing the HoQ for this specific fruit product. In the next sections, we present how to fill in the "rooms" of the HoQ in accordance with Jongen and Meulenberg (1998, 2005). Challenges, bottlenecks and gaps in the application of HoQ are also highlighted.

Consumer Requirements - WHATs Room

The first room of the HoQ is called the WHATs room and contains a list of customer requirements. The requirements can be defined as product attributes essential for satisfying consumer needs and for surpassing competitive products. Customer requirements are usually investigated in market and consumer research.

To fill in the WHATs room, a number of ISAFRUIT results were selected. First, consumers' ranking of important product characteristics when buying new fruit products was employed. Onwezen et al. (2010) investigated nine characteristics which consumers were asked to rank in decreasing order of importance: *Healthy*, *tasty*, *safe*, *reasonably priced*, *naturally produced*, *appealing*, *convenient to consume*, *a good brand* and *is familiar to me*. Based on the results, five of the most important product characteristics were chosen for further analysis. Since, at this stage of product development, "*reasonably priced*" does not seem to be relevant, it was excluded. *Healthy*, *tasty*, *safe* and *naturally produced* were included in the WHAT room. Authors would like to stress that this selection was done only for the sake of simplicity of the example.

The mentioned characteristics might be differently interpreted by consumers and therefore difficult to implement. For further work with the HoQ, it is necessary to understand what consumers mean by those terms in reference to the specific product, dried fruit. Exploratory qualitative research has been conducted within ISAFRUIT (Jesionkowska et al., 2007, 2008, 2009a, 2009b; Sijtsema et al., 2008; Kraszewska et al., 2008). Those results were used to obtain more insight into four chosen characteristics related to dried fruit.

Table 1. Overview of the ISAFRUIT results used in the paper.

Discipline	*Product*	*Country polled* *Polling method and number*	*Measures*	*Work Package*	*References*
Consumer	Dried fruit	Poland, The Netherlands, Creative group discussions N = 28	Perceptions	3.3	Jesionkowska et al., 2007
		Poland, The Netherlands, France Questionnaire N = 1092			Jesionkowska et al., 2008 Jesionkowska et al., 2009a Jesionkowska et al., 2009b Sijtsema et al., 2008
Consumer	Apple crisps/ dried apple	Greece, The Netherlands, Poland, Spain Focus group interviews N = 102	Perceptions	1.3	Kraszewska et al., 2008
	Black currants	Greece, Spain, Poland and The Netherlands Consumer survey n = 1972			Onwezen et al., 2010
Sensory	Dried apples Dried blackcurrants Dried sour cherries	Poland Sensory panel	Sensory evaluation	3.3	Konopacka and Jesionkowska, 2008 Konopacka et al., 2009b Konopacka et al., 2010
	Dried blackcurrants Dried sour cherries	Poland, The Netherlands, France	Acceptance		Jesionkowska et al. (unpublished) Jesionkowska et al., 2010b (unpubl.)
Technology	Dried apples Dried blackcurrants Dried sour cherries		Macro and micro nutrients	3.3	Klewicki, 2007 Klewicki, 2008 Konopacka & Jesionkowska, 2008 Konopacka et al., 2008 Konopacka et al., 2008 Konopacka et al., 2010 Uczciwek et al., 2007a Uczciwek et al., 2007b
Overview of all activities concerning dried fruit	Dried apples Dried blackcurrants Dried sour cherries		Perception, acceptance, technological trials	3.3.	Konopacka et al., 2009a

Healthiness

In one focus group study participants were discussing the *healthiness* of dried fruit (apple chips) (Kraszewska et al., 2008). The general opinion in four investigated EU countries was that dried fruit is healthy when it is for example nutritious and contains healthy ingredients; it is produced in a natural way, which in their perception means that it does not contain chemical residues, preservatives or any other artificial additives. Healthy nutrients most often mentioned by respondents in a focus group were vitamins and fibres (Kraszewska et al., 2008). Based on this consumer survey (Jesionkowska et al., 2008, 2009) we may indicate two other attributes that consumers are also interested in: antioxidants and substances which positively influence intestinal microbiological flora (prebiotics).

Taste

Based on the discussions with participants in the focus groups (Kraszewska et al., 2008) it might be concluded that sweetness, acidity and overall flavour (often referred as natural flavour or natural fruitiness) are the most important components of taste.

Safety

For dried fruit, *safety* was also referred to by focus group participants (Jesionkowska et al., 2007; Kraszewska et al., 2008). First, dried fruit was perceived as **not safe** when it is processed in an unnatural way (for example frying). Second, dried fruit is perceived as not safe when it contains preservatives.

Naturalness

Natural production in reference to a fruit product was mostly defined as a natural way of processing (no frying), in which nutrients and healthy ingredients are retained in the final products and no preservatives or other artificial components are used. Summing up, the consumer requirements list consists of the following attributes: *healthy*, *tasty*, *safe* and *naturally produced*.

Customer Importance Ratings

It is important for a company to know which characteristics are more relevant than others. In a real market, due to the costs and limited resources, prioritising and even compromising is often required. Prioritisation of consumer preferences should be done by means of consumer research. Consumers are usually asked to assign to each of the attributes a number from 1 to 5, where 1 is the least important and 5 is the most important. Since those results are not available, we simply present the attributes in order of their importance as stated by Onwezen et al. (2010) (Table 2).

Table 2. Customer requirements in order of importance.

WHAT's – consumer attributes
Healthy
Tasty
Safe
Naturally produced

Product Requirements – the HOWs Room

In this part of the HoQ, each of the product attributes (each of the WHATs) should be translated into one or more technical attributes. This can be achieved by means of answering the question: "What technical characteristics of the product influence this specific product attribute required by consumers?" First of all, to answer this question, a good understanding of each of the consumer attributes is vital. It is necessary to know what exactly determines consumer satisfaction from the specific products. Second, an expertise of technologists, who are aware of the production details, must be available to find out what technical attributes are responsible for the consumer evaluation of product attributes.

We will try to define precisely each of the consumer attributes to enable assigning one or more technical attributes to each of them.

From the previous section, it is already known that *healthiness* has several meanings in reference to a dried fruit. Based on the above mentioned results healthiness might be defined as:

- Containing valuable or desired nutrients (e.g., vitamin C and fibre)
- Containing no artificial additives (e.g., preservatives)
- Containing functional ingredients (e.g., antioxidants and prebiotics).

In the case of healthiness it is quite straightforward to list the technical attributes underpinning product characteristics: *vitamin C content*, *fibre content*, *antioxidants content*, *prebiotics content* and *artificial additives content*.

Based on the experimental research (Konopacka et al., 2009b, 2010, unpublished; Konopacka and Jesionkowska, 2008) and consumer research (Jesionkowska et al., 2010a) we are able to confirm that the evaluation of *taste* from the technological point of view is influenced by many substances. Most of all, product sweetness, acidity and the proper balance of those two affect sensory acceptance or rejection of consumers. Therefore, *content of sugar* and *content of acid* are included as a measure of consumer attribute of tastiness. Furthermore, during the experimental research on dried cherries and black currants, fruits were infused with different osmotic agents that also influenced their final characteristics. Dehydration time and osmotic agent were found to be strongly related to the overall flavour (Konopacka and Jesionkowska, 2008). Therefore, four technical attributes were chosen to measure consumer attribute of taste: *content of sugar*, *content of acid*, *dehydration time* and *osmotic agent*.

Interviewed consumers associated safety with the *level of artificial additives* in a product and with the *method of processing*. As the meaning of the attributes *healthiness* and *safety* is overlapping (a healthy product contains no artificial additives and a safe product contains no additives), for the first part of the consumer definition of safety, HOW is already established. The second part of the definition of safe – natural processing method – could be measured by the *fat content*. During the focus group discussion, when discussing apple chips, participants were very much against frying fruit. They strongly believed that frying is not healthy and does not match the image of fruit. Once given fried apple chips, respondents immediately evaluated them as unhealthy products, indicating frying was the problem. Whereas, presented with dried apple slices, respondents evaluated healthiness, safety and naturalness of this product really high. Summarising, if the level of fat is close to zero, this would ensure that a product was manufactured in a natural and healthy way.

The last product attribute – *natural production method* – consists of *natural way of processing*, *high content of (desired) nutrients* and *no usage of artificial additives* or *fat*. Each of those components of "natural production" are already part of the characteristics of healthiness and safety, so there is no need to establish any additional HOWs for this characteristic.

Relationship Matrix

In this room the relations between the each WHATs and each HOWs are established. Different symbols are used to assess the strength of relationships. This part of the House of Quality requires close cooperation between consumer and technical scientists. The order of technical attributes is determined by the relevance to the consumer requirements, i.e., first technical attributes measuring healthiness are listed, next, attributes related to tastiness, etc. (see Table 3).

In close cooperation and through intensive discussions between consumer and technical scientists, the relations between the WHATs and HOWs were evaluated. Below, we will describe some of the relations, which exemplify the typical procedure of filling in this room of the HoQ.

Technical attributes established to "measure" **healthiness** are *vitamin C content*, *fibre content*, *antioxidants content*, *prebiotic content* and *artificial additives content*. The relations between healthiness and most of the technical attributes are expected to be strong. Additionally, other technical attributes were identified to play an important role, e.g., *fat* and s*ugar* content.

Interestingly, from a nutritional perspective, two of the technical attributes are overlapping, as vitamin C belongs to the antioxidants. From consumers' perspective these are two separate attributes. Since the consumer preferences have a superior role (QFD is a consumer oriented process), and those two consumer attributes seem to be very important for consumers, we decided to keep them separate.

Table 3. Relationship matrix.

Consumer requirements (WHAT)	*Technical attributes (HOW)*	*Vitamin C*	*Fibre*	*Antioxidants*	*Prebiotic*	*Artificial additives*	*Fat content*	*Sweetness*	*Acidity*	*Dehydration time*	*Kind of osmotic agent*
Healthy		•	•	•	o	•	•	•		∇	o
Tasty						•	∇	•	•	•	•
Safe						•	•	∇			
Natural		•	•	•	∇	•	•	∇		∇	

Relationships: • strong o medium ∇ weak

For the consumer requirement *safe*, two technical attributes were selected as having a substantial influence i.e., *artificial additives* content and *fat* content. During the analysis of the relations between the technical and consumer attributes, a weak relation was identified between *the content of sugar* and *dried fruit safety*. The procedure for the consumer requirements “natural” and “tasty” was similar.

Correlation Matrix

The correlation matrix is a room where the correlations between the technical attributes are identified. The correlation may be positive or negative. If the correlation between the attributes is positive, it means that one attribute supports (strengthens) another. Negative correlation means that the attributes affect each other in the opposite way.

The identification of the relations between the attributes is most important from the perspective of a company’s resources (Costa et al., 2000). Companies’ financial resources are rather limited and changes in the product (to satisfy customer requirements) are usually costly. A positive correlation between the attributes enables fulfilling customer requirements at lower cost. Therefore, positive correlations in the correlation matrix are advantageous for a company.

Contrarily, negative correlations mean that the technical attributes are in conflict with each other, so both of them cannot be achieved in the same time. Such situation requires making a choice to prioritise which technical attributes will be changed according to consumers’ wishes and which not. Negative correlations in the HoQ correlation matrix may indicate technological barriers to overcome. This means that due to some developments in technology, the adverse relation of the attributes could be changed and then trade-offs between consumer wishes would not be necessary (which leads to higher consumer satisfaction).

Figure 1 shows the matrix of correlations for the technical attributes relating to dried fruits. Strong positive correlations were determined between *dehydration time* and *content of prebiotics*, *sugar* and *acidity* and between *a kind of osmotic agent* and *sugar* and *acidity*. Strong negative correlations were defined between two pairs of attributes. First, the attribute of acidity and sweetness are in conflict – the more acid the dried fruit contains, the less sweet it is and the more amount of sugar is needed to achieve the taste wanted by consumers. The second strong negative correlation between *dehydration time* and *content of antioxidants* indicates that the longer the fruit is dehydrated, the lower the content of antioxidants in the final product.

Technical Importance Ratings

When the rooms of the relationship matrix and consumer importance ratings are filled in, usually technical importance ratings are counted. Since we do not have consumer importance ratings, it is not possible to compute technical importance ratings. However, reflection on the relationships and correlations is still possible.

A matrix of relationships allows us to indicate the technical attributes with the highest potential to increase consumer satisfaction for a product (Fig. 2). The high strength of the relationships and the number of relevancies to the customer requirements indicate that absence of *artificial additives* is the most important attribute for dried fruit. The second most important attribute seem to be *fat content*. This requirement is easily fulfilled, when fat is not used in the drying of the product. Absence of additives and fat may decrease the perceived risks related to purchase and consumption of dried fruit.

The next attribute, which has a couple of strong relationships and many relationships to consumers' requirements, is *sweetness*. This attribute seems to be a bit more difficult to interpret. First, it was found to be strongly, negatively related to healthiness of the product. This means that the higher the sugar content, the less healthy the product. On the other hand, it is one of the attributes strongly linked to taste of the product, and the relation here is positive – the sweeter the product, the better the taste. Thus, sweetness supports one of the attributes (taste) but at the same time it is in conflict with another (healthiness). Both consumer attributes, healthiness and taste, are truly important to consumers. Development of dried fruit by using natural fruit sugar might be a solution to increase the healthiness of the product, without lowering its tastiness. Thus, technological as well as additional consumer and or sensory studies might be helpful. Anyway, the many relationships of the attribute *sweetness* with consumer requirements indicate that this attribute should be given much attention when developing a new product. Finally, three attributes related to the content of healthy ingredients desired by consumers, *Vitamin C, fibre* and *antioxidants*, seem to significantly influence consumer perception of dried fruit.

Vitamin C									
Fibre									
Antioxidants	+								
Prebiotic		+							
Artificial additives	+		+						
Fat content									
Sweetness			-						
Acidity							--		
Dehydration time	-		--	++			++	++	
Osmotic agent	-	+	-				++	++	+/-

Correlations:
- ++ strong positive correlation
- \+ positive correlation
- (No sign) no correlation, irrelevant
- \- negative correlation
- -- strong negative correlation

Fig. 1. Matrix of correlations.

DISCUSSION: RECOMMENDATIONS AND LIMITATIONS

Multidisciplinary teams have gathered data on dried fruits within the ISAFRUIT project and those data have been used for application of the HoQ. This example shows some limitations. With regard to the tool of HoQ the following issues should be addressed.

First, when considering product attributes important for consumers, we found that those attributes have close and sometimes overlapping meaning as perceived by consumers. Fruit healthiness, safety and naturalness are close to each other according to consumers' perceptions. In our case, additionally, the selected attributes are rather general, which makes them difficult to operational context. Thus it is not only important to know what is relevant to consumers, but also what do consumers mean by the mentioned attributes. In this study, qualitative research was very helpful in understanding what is behind the terms used by consumers.

Correlations:
++ strong positive correlation
+ positive correlation
(No sign) no correlation, irrelevant
- negative correlation
-- strong negative correlation

	Vitamin C	Fibre	Antioxidants	Prebiotic	Artificial additives	Fat content	Sweetness	Acidity	Dehydration time
Vitamin C									
Fibre									
Antioxidants	+								
Prebiotic		+							
Artificial additives	+		+						
Fat content									
Sweetness			-						
Acidity							--		
Dehydration time	-		--	++			++	++	
Osmotic agent	-	+	-				++	++	+/-

Consumer attributes / **Technical attributes**	**Vitamin C**	**Fibre**	**Antioxidants**	**Prebiotic**	**Artificial additives**	**Fat content**	**Sweetness**	**Acidity**	**Dehydration time**	**Kind of osmotic agent**
Healthy	●	●	●	o	●	●	●		∇	o
Tasty					●	∇	●	●	●	●
Safe					●	●	∇			
Natural	●	●	●	∇	●	●	∇		∇	

Relationships: ● strong o medium ∇ weak

Fig. 2. House of quality for dried fruit.

Second, deep understanding of what consumers want fostered cooperation of consumer scientists and technical scientists. When consumer requirements were precisely expressed, finding relevant technical attributes was quite easy. Therefore, both groups of scientists should be open minded and constructive in their communication and a close co-operation between consumer and technical scientists is an important issue.

We also found out that it is hardly possible to apply this method to a category of products such as dried fruits as is almost impossible to establish appropriate technology attributes (HOWs) for such a broad category. We would rather recommend it for one very specific product. For example, in our study, we used results of the experimental and sensory research on dried sour cherries and blackcurrants. Combining those two products in one HoQ seems inappropriate: the original content of vitamin C is very high in black currants and very low in sour cherries. The relation of the attribute *Vitamin C* with consumer requirements will be evaluated differently for those two products: – for blackcurrants, it will be an advantage but in case of sour cherries it will be a disadvantage, which should be overcome. Even within different cultivars of the same fruit, the relations between the HOWs and WHATs may be different. Therefore, on no account can one "template" be established for many products. Careful selection of consumer requirements and technology attributes and defining the relationships between them should be carried out each time by means of the market and consumer research and close co-operation between consumer and technical scientists.

Finally, one should remember that those two scientific areas, consumer and technical research, are quite distant from each other, which makes communication between them difficult. We often used the same terms with a different meaning, for example – product quality, safety or fruit variety, etc. In general, consumer scientists seem to think more "qualitatively", whereas technical scientists are much more "quantitatively" oriented. Such different backgrounds make interdisciplinary communication a challenge. We have strongly experienced that substantial amounts of time spent on understanding each others' perspectives and explaining the terms and definitions at the beginning of cooperation may smoothen and facilitate activities undertaken together. Specifically, establishing technical attributes and defining the relationships between the customer and technical requirements is an activity which must be done in very close cooperation, with the possibility for open discussion during the whole process of product development.

Next, we would like to present some issues with regard to the method applied. Data were gathered which considered fruit in general and different types of dried fruit products. In this exercise ranking of consumer attributes used in a WHAT room was gathered in reference to processed fruit products generally, while other data were based on specific dried fruit products such as dried apple or dried blackcurrants or sour cherries. It is plausible that the characteristics important for the consumers when thinking of new dried fruits and new processed fruits are similar; however, we may not be sure whether they indeed would be the same. Therefore, our recommendation is to take into consideration the same product for all the different rooms. In particular, fear from frying fruit during the production seems to be a consequence of example selection during the qualitative study – i.e., apple chips. It is plausible that if another dried fruit example was chosen for that study, the issue of "frying" might not have popped up. Since "no fat" appeared to be one of the most influential technical attributes, we would restrict this result to the fruit chips only. Once again it proves that this method should be applied for one specific product at a time.

Further, one should also pay attention that we have not presented all the rooms of the HoQ. Specifically, we have not elaborated the planning matrix in which the product is compared with similar competitive products since we did not have data available for those analyses. When finishing the product development of dried fruit, additional data are needed to also "build" those rooms.

CONCLUDING REMARKS

Although several limitations of the application of HoQ to food product development are faced due to its complexity and time consuming character, it still seems a promising approach which structures and organises the communication between consumer and technology scientists. Especially, this integration of both sciences seems promising in a consumer oriented approach.

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Exploration of Consumer and Sensory Research in the House of Quality
Sweet and Sour Taste Preferences for Fruit

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Abstract

Taste is often a very important or even decisive motive in food choice. Taste is specifically studied in sensory research but is also considered in consumer research in a more generic way. In order to develop successful new fruit products, the ISAFRUIT House of Quality (ISAFRUIT HoQ) might be a useful approach in which taste as a technical attribute and taste as a consumer attribute are linked. The aim of this paper is to explore the application of consumer and sensory science in the ISAFRUIT HoQ with focus on sweet and sour taste preferences for fruit. Within ISAFRUIT, qualitative and quantitative consumer research has been carried out to explore taste preferences in general. Additionally, sensory research has been conducted on different apple cultivars in several European countries. Implementation of results in the ISAFRUIT HoQ has revealed the possibilities as well as the limitations when relating consumer demand attributes to technical sensory attributes. For the selected attributes, sweetness and sourness, consumers and experts have the same expression but a different interpretation. Although the linkage of sensory and consumer research seems of absolute relevance for product development, the combination of both in the ISAFRUIT HoQ is quite complex due to the dynamic character of consumers' food preferences as well as fruit products.

INTRODUCTION

Development of new fruit products is one possibility to increase fruit consumption, whereas taste is a very important or even decisive motive in food choice. Taste can be studied from different perspectives. In consumer research, taste is often just one of the motives studied, while in sensory research it is the actual taste of food which is judged. Within the ISAFRUIT project, consumer as well as sensory research have been performed to get an insight into consumer perceptions and preferences for fruit. Viaene and Januszewska (1999) have combined these disciplines, but to our knowledge no applications are available to link the results of consumer and sensory research in a HoQ for fruit. Therefore, the aim of this paper is to explore the linkage of sweet and sour taste preferences studied in consumer and sensory research. To evaluate whether this application might be useful for development of new fruit products, sweet and sour taste preferences are chosen as an example due to their high importance in food choice.

In this paper we will share our experiences and discuss the advantages and disadvantages of this approach.

METHOD

In previous sensory research within the ISAFRUIT project, appearance and taste acceptance was evaluated for 11 apple cultivars by consumers in Poland, Italy, Spain, Switzerland, France, The Netherlands and Germany (number of respondents = 4290). Preference mapping combining sensory analysis resulting from an evaluation of the 11 cultivars by a trained panel, and data from instrumental quality assessment and acceptance data from the consumer test have been explored in this study. Consumers were grouped in clusters based on the scores given to the cultivars tested. Cluster analysis (SAS FASTCLUS procedure) was performed based on the Euclidean distances between consumers calculated through the SAS MDS procedure.

In Poland, Greece, Spain and The Netherlands an additional qualitative and quantitative consumer study was done. In total 94 persons participated in focus groups about consumers perception of fruit and motives and barriers related to fruit consumption (Briz et al., 2008). In the quantitative study, respondents (n = 2083) from the same 4 countries filled in an online questionnaire in which preferences and consumption of fresh fruit, sweet snacks, salty snacks, freshly squeezed orange juice and dried fruit were measured for different consumption moments (situations in which the food was consumed), as well as basic taste preferences, health, convenience, price orientations and routine behaviour with regard to fruit (Onwezen et al., personal communication).

RESULTS

Effects on Sensory Apple Quality Attributes (Technical Attributes)

Identifying which sensory attributes drive consumer preference was one of the aims of the sensory research within ISAFRUIT. Consumers were grouped in 2 Megaclusters according to the method described above. Preference mapping indicated that sweetness was one of the most important variables related to flavour acceptance. Acceptance of cultivars for consumers in the larger cluster can be explained by sweetness of the fruits. The higher the sweetness, the higher the acceptance of the cultiar. With regard to the other cluster, the preference is based on sourness of the fruit. The higher the perceived sourness the higher the preference for this group of consumers.

Impact on Consumer-Demand Related Attributes

In line with the literature, ISAFRUIT results show that ‘taste’ is the most important motive when consuming fruit (Zimmermann et al., personal communication). The focus group data indicated other issues with regard to fruit consumption (Briz et al., 2008). For example consumers mention flavour related issues such as; ‘eating fruit is a pleasure’, ‘it is refreshing in summertime’, ‘seasonal fruit is cheap and good’ and ‘there are tempting fruit varieties’. These results show that taste is an important determinant for food choice. However, according to the segmentation study not every consumer pays the same attention to taste. In addition, consumers prefer different types of fruit in different situations at home and out of home (Onwezen et al., personal communication).

Thus, consumers’ motives vary, and there are also barriers experienced when consuming fruit. While the appearance of fruit is usually a motive to eat fruit, it might also be a barrier. If there is a lack of high-quality fruit, the available fruit may not fulfil consumers' expectations.

Besides the motives and barriers, taste preferences were studied in this consumer research. with 3 statements ('I prefer salty over sweet food', 'I prefer sweet over sour food', and 'I prefer salty over sour food'). 39% of consumers did not have a specific preference, while 29% had a preference for salty food, 21% for sweet and 11% for sour. However, preferences vary between consumers from different countries (Sijtsema et al., personal communication).

Taking the consumer as well as the sensory research into consideration, sweet and sour preferences are measured in two different ways; one is based on the participants' own perception, the other is based on acceptance of the taste of different types of apple.

Implications of the Results in the House of Quality

This volume presents and discusses a HoQ for fresh apple. In this HoQ, a choice of relevant descriptors has been implemented in the technical part 'sensory descriptive attributes', divided into taste, aroma and texture. Focusing on 'sweetness' and 'sourness' in the current work, these attributes have been related to the consumer demand related attributes 'good', 'sweet', 'sour' and 'fruity'. The alignment of common understanding of sweetness and sourness in consumer as well as in sensory language does allow to build a relationship. In terms of 'sweetness' (technical attributes in HoQ), a positive relationship to what consumers perceive as sweetness. In terms of sourness (consumer-demand related attribute in HoQ) a negative relationship can be identified. For 'sourness' (technical attribute), the relationship to what consumers perceive as sourness (consumer demand related attribute) is positive. On the other hand, a negative relationship is found to what consumers perceive as sweet (consumer demand related attribute). The relationship between good taste (consumer demand related attribute) and sweet and sour taste (technical attribute) follows an optimum for the average consumer.

DISCUSSION AND RECOMMENDATIONS

In this HoQ exploration, only a few selected consumer and sensory attributes are linked, therefore it is not intended to be complete.

First, the evaluation of consumers with similar preferences results in their allocation to different clusters in consumer and in sensory research. There is no average consumer, especially when including demographics like age, gender, country, origin, etc. The HoQ as it is currently constituted, only allows data entry for the average consumer. Moreover, the taste preferences of the 2 megaclusters evolving from sensory research are opposite. To illustrate the relationship between consumer demand oriented and technical attributes, a selection of one cluster has to be made, hence limiting the information to the selected cluster. Chosen data was related to the bigger cluster. To cover the behavior and preferences of the various consumer segments, different HoQ's could be applied, representing one cluster each. For further research, application for specific cluster of consumers might be of interest.

A second issue closely related to segmentation is that the research done within

ISAFRUIT goes across countries. In the sensory study, consumers of seven countries participated; the consumer studies were conducted in four countries, with The Netherlands, Poland and Spain in both. Additional analyses are needed to get insight into cross-country preferences for taste.

Another parameter might be seasonality of the fruits: consumers might change their habits according to outside temperature. The product acceptance testing for ISAFRUIT took place in February, where 68% of the participating consumers were allocated to the cluster preferring sweet apples. From qualitative research on apples, it is known that during periods of cold temperature in wintertime consumers show a preference for sweet over sour apples (Good et al., personal communication). This is an additional element which might be useful to consider in segmentation.

Another aspect related to variability of consumers, is that consumers' preferences and behavior are depending on various parameters such as moment and situation of consumption (Onwezen et al., personal communication).

The terminologies for the consumer demand related attributes and the technical attributes are partially overlapping. However, their understanding by consumers and experts might be different. In sensory research, the attributes are substantiated with definitions to reach consensus. Consumer language and expression, however, is an individual language based on personal experiences. As far as basic taste qualities are concerned, there is a relatively common understanding of sweetness and sourness. Hence the term 'taste' does include a more complete description for the consumer, since 'taste' is used in a more general way, in comparison to a sensory panel which is trained to act like a measure instrument giving a precise and one-dimensional response to each product characteristic. Therefore, the terminology in the ISAFRUIT HoQ, does not necessarily have the same meaning although the wording is the same. Regarding other attributes like aroma and flavor, e.g., fruitiness, we need also to know the consumers' understanding and what associations they have. To get these insights, the linguistic understanding of consumers needs to be further studied.

Satisfaction with the quality of most recently purchased product is influencing repurchase behavior and might change preferences. Thus, neither the consumer nor the product follow a static law.

All aspects described above seem to refer to the fact that although an ISAFRUIT HoQ is static, it might be helpful for taste-related aspects to develop it further in a more dynamic way. This would require an indication of static versus dynamic data in the HoQ, indicating the validity of the data. Those dynamics should be considered when applying the ISAFRUIT HoQ and their adoption and specifications require more research and time, and would thus be more expensive. Having reflected on the limitations we also want to mark some challenges. The HoQ approach indicates the possibility of linking technical attributes of sensory research with consumer demand related attributes. This approach is not only bridging the communication of technical scientists with consumer scientists but also offering possibilities for new product development or further research on intended consumer behavior with actual behavior, thus linking consumer research with sensory research. Enabling this communication and collaboration, the ISAFRUIT HoQ offers a structured approach to determine what research in the linkage of technical sensory attribute with consumer demand attributes is still needed.

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Special Case: How to Place Economic Attributes in the House of Quality?

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Abstract

Price is one of the attributes which most influences the buying behaviour of consumers. Producer price and consumer price do not appear very related, and do not seem to be under the control of a common determinant. Consumer price may respond to perception of consumer-related attributes, e.g., consumers are willing to pay more for organic apples. Producer prices for organic products may be higher, but other technical aspects impinge on productivity and can affect profitability of the operation. Decision support systems can assist growers in making the decision to switch from IP to organic production, but these tools could benefit by a HoQ approach that would better define the relationships (and their value) between consumer-demanded traits and technical aspects addressing these traits.

INTRODUCTION

Price is one of the attributes which most influences the buying behavior of consumers. For exactly the same apple, consumers will normally buy the apple with the lowest price. Apple growers have the opposite interest related to the price. The producer price for apples influences the income of the apple grower. The price for apples is determined by both supply and demand. The price level is determined by the point at which quantity supply equals quantity demand. Hence the yield and surface of apple orchards worldwide are also an important factor for price regulation. To maintain the long term production of apples in a region, the turnover of the orchard should be high enough to allow new investments and to pay for the income of the apple grower. This can be determined by high grower prices, high yields and/or low costs. Good management skills help to influence those two aspects and to reduce production costs. With a good strategy, apple growers can improve their turnover. In the Work package 5.3 Profitfruit of the ISAFRUIT project two instruments have been developed to help growers strategically. The first instrument consists of Excel calculation sheets that help growers to calculate their own turnover, production costs, gross margin, marginal gross margin and income; the second instrument aims to help growers with the decision whether or not to switch to organic production. Agronomic and economic data have been collected and analyzed to compare the costs of the organic and IP production (Germany) and to determine the success factors for apples growers (Switzerland). First we illustrate how we chose economic attributes being relevant for consumers in order to insert economic case studies into the ISAFRUIT House of Quality (HoQ). Afterwards, we describe more in detail economic experiments of ISAFRUIT at farm level and how economic factors have been measured. We will discuss how this economic part of the project contributes to innovation.

METHODS

Selection on Apple Quality Attributes (Technical Attributes)

To choose the economic attributes, we considered which factors are important for growers. From Mouron and Carint (2001), we know that yield, price of the best class fruit and the proportion of the best class fruit are key factors influencing more than proportionally the labour income of apple growers. Labour income is returns minus production costs without labour costs divided by the time needed for production. We combined those key factors in super-power key-factor: the yield of the best class (kg/ha). The second economic attribute we chose was consumer price. This is the price (€/kg) consumers pay in the store for a given amount and quality of apples. This factor is related to producer price (€/kg), the price paid to growers for a given amount and quality of apples. This is also a key factor. In Switzerland, producer price is between 20% and 30% of the consumer price (FOAG, 2009). The relation between producer and consumer price is not stable. It fluctuates with the production in and out of the region, with the preference of consumers and with the market power relation between fruit growers and traders. The relation between production and consumer price is also different between countries. We chose consumer price as technical attribute because we assumed that it has a more important relation to consumer demand than the production costs or producer prices. However, producer price could also be a valuable technical attribute.

The scientific work carried out in WP 5.3 was at farm level. By this work researchers developed information and tools for apple growers to help them to make sound decisions to ensure the future of their operation.

Calculation Model Profitfruit for Apple Growers (Groot and Roelofs, 2009)

With this tool, whose calculations are based on a standard data set for three countries, growers can insert production data of their own orchard and simulate the effects on profit, income and other economic key-data of changes in price, yield or labour costs (Groot and Roelofs, 2009). By using the model, growers can estimate their own production costs and become aware of the influence of some important factors on income, helping to guide decisions about investment and other strategic plans. The model can for instance help growers to choose new cultivars, and assess their effect on yield of the percentage of fruit in the first class, and therefore indirectly the consumer price. However, in the present version of the HoQ cultivar is not included as a technical factor.

RESULTS

Decision Tool Organic Production

Due to higher producer prices, growers are interested to switch to organic production. This important decision can only be made with technical and scientific criteria (Warlop, 2008). When growers use the tool to make the decision to switch to organic they have more chance to succeed in the production of organic apples. The finalized tool should tell the fruit grower by using agronomic, technical and economic criteria if his orchard is adapted to organic. To avoid failures in the long term strategy, the decision tool should suggest which pattern should be improved before considering the transition, to avoid strong losses. The decision of the newcomer organic grower is better supported and based on technical and agronomic criteria about the orchard. The objective of using a decision tool is to reduce the risk for growers that switch form IP to organic production. With less risk (because of pests damages or other problems) the yield results could improve. With a larger organic production consumers have more choice (for example different quality) and the price for organic fruit could drop.

DISCUSSION

Impact on Consumer-Demand Related Attributes

When linking economic attributes (yield of best class and consumer price) to consumer demand related attributes (size, texture, composition, smell, appearance, ripeness) most of the time an unknown or very complicated relationship can be found. For example if the yield of the first class is higher it could be that also the appearance of the apples is better – because there are more apples of the first class. There is very little information available about yield of the best class on, respectively, consumer prices and texture, composition, smell, appearance and ripeness.

The consumer demand-related attribute “price” (low and affordable) has on the other hand a clear relationship to the economical attribute “consumer price” and “yield of the best class”. To achieve a higher income, a grower needs to produce according to consumer wishes and/or attain more yield of the best class and/or reduce costs. A possible choice is to choose club cultivars (Maas et al., personal communication). Some of these are selected based on consumer research. Consumers are also willing to pay higher prices for quality apples. The costs for growing are often higher for the growers, but as long as the returns are also higher the growers’ income can be positive.

Theoretically this means that the grower will produce consumer-demand related apples only if he can achieve a better income than by producing and harvesting standard apples. This can be reached for example by matching consumer-demand related attributes with cultivars with higher grower prices. However, this does not confirm their willingness to pay for research. For consumer quality is a basic requirement and the extra price is not a logic next step. For apple growers this is a big dilemma because by matching consumer-demand related attributes with new cultivars, risk and production costs will rise.

The HoQ connects in a sophisticated way innovative economic processes and products – economical attributes – to recognition of the importance of innovations by the consumer. This means for the economic perspective that process improvements and product improvements have to be matched with consumer demands. This matching discussion will be of interest for the fruit researchers valuing the importance of innovations and therefore the success of fruit growers but also of the entire apple chain. As acceptance of innovations is usually measured by traditional sensory and consumer preference mapping, it will be studied how monetary value can be added to new fruit processes or fruit products. The most indicative economic factor will be willingness to pay or buy, but as this item was not part of the Pillar 1 on the ISAFRUIT project consumer approach other factors as price orientation and innovativeness of consumer demand were introduced and linked to economical factors.

At this moment the technical attributes chosen for the economic part are the yield of the best class and the consumer price. In the economic part of the ISAFRUIT project (WP 5.3) we did not evaluate the consumer price. In different experiments only data about producer price and production costs have been measured. However, because those data are less relevant for consumers, consumer price has been chosen as a technical attribute. This implicates different assumptions, as a known relationship between consumer price and producer price. By choosing different technical attributes as producer price or production cost the evaluation of the effect of the ISAFRUIT research on the attributes would be more specific. However, the impact on consumer-demand related attributes will need much more research, including about the market situation and about price-elasticity. Using the HoQ in this case, we think that the experience teaches us to add more specific attributes to the HoQ: like cultivar, costs/kg, cost price, maybe even production system. The way fruit is produced influences the consumer values. It would be interesting to compare for example how consumers would react to fruit from old, extensive orchards, compared to fruit from new, “high tech” orchards with hail netting, intensive plantings and so on. By adding these more technical attributes, the effect of different strategies on consumer-demand could be even more clear.

RECOMMENDATIONS

To better structure the link between technical research and consumer demands, more consultation between technical and social scientists are needed to implement the right criteria towards the HoQ. Perhaps in other sectors examples can be found to link economic data and can be use as an example for the fruit sector and perhaps the agricultural sector.

Given the current development of the HoQ, we can make some remarks. We have three economic categories:

1. economics, of investments in orchards and production technology linked more towards different consumer demands like sensory traits, less residues and higher quality;
2. economics of farm income like yield, best class but also production costs and producer prices linked to consumer prices although the price-making in the fruit chain is not transparent at all and the margin of the producer is a lesser indicator for the margins in the chain and the consumer price;
3. economics of added value instruments like organic and regional production

which will apply to other factors of consumer demands like health, convenience, sustainability, cultural/national orientation, etc.

For apple growers price is one of the most important factors for their income. In years with overproduction producer price drops to a low level. The drop of prices has more than proportional consequences on farm income. Growers are not able to reinvest in their orchard and if the price drops on a long term growers will have to stop their production. Decision tools would allow growers to better evaluate different scenarios for their decisions.

To produce apples with consumer-relevant attributes, one or more cultivars with that specific quality should be created. However, according to Kellerhals (personal communication) mainly the following aspects are today important for breeders: the suitability for storage, the colour/aspect and size of the apples, the firmness, the juiciness and the yield. Apples should not suffer from major diseases or defects.

Today it is the trade/chain partners that usually choose the cultivar they will sell. Apple growers choose their cultivar based on recommendations from the trade. To introduce new cultivars for example a long time period is needed. For breeding and first commercial production, over twenty years are necessary. Apple orchards are also long term production. The apple orchard has a life time of 12 to 20 years (Switzerland) or 12 to 14 years (The Netherlands). New cultivars take time to establish and reach a critical production level. Growers cannot switch from year to year to a new cultivar – so they cannot follow trends for a couple of years. Only with a concept for cultivar, production system and added value that also involve the market and the trade is possible to meet consumer demand and increase fruit consumption.

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Conclusions from the ISAFRUIT House of Quality Exercise and Reflection on Its Potential
A Learning Case in Interdisciplinary Research

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Abstract

The ISAFRUIT project launched in 2008 the Vasco da Gama – process for developing a tool with which it would be possible to link social and technical sciences in order to evaluate the extent to which technical achievements of the project for increasing fruit consumption in Europe properly address consumer demands. The ISAFRUIT House of Quality has been developed subsequently and is available for further development and use (www.isafruit-vdg.ch). Conclusions and experiences are shared in this article for stimulating further respective developments. A critical view is presented in the achievements made so far. The applicability of the tool is discussed, as well as problems of avoiding a disintegrated view and maintaining an integrated approach for meeting the reality and creating the impact addressed: increased fruit consumption. Also, conceptual achievements and drawbacks are reflected, the experiences made in developing successful interdisciplinary work, the crucial role of communication and the potential of the tool. In conclusion, the ISAFRUIT House of Quality is appreciated as a useful tool for stimulating interdisciplinary exchange to the benefit of better meeting consumer demand, even if yet quite complex, requiring further conceptual development and simplification for application in product and technology development.

THE PRINCIPAL CONCLUSION

Whatever you read from in this *Scripta Horticulturae* volume, be it all or just one article, you become aware that we report about something that is not finalized but in progress. If there is an overriding conclusion at this point it is that we have reached our principal goal: launching and nourishing a process was in fact our main objective or, quoting Confucius (as it seems according to some sources): the journey is the goal. What we attempted was about "bridging between research disciplines aimed to discover if the technical research conducted indeed addresses consumer-demand related requirements discovered by the social scientists in the project and if this combined research could contribute to increased fruit consumption in Europe" (Bertschinger et al., 2011). The method to carry out this process, eventually found in the House of Quality (Hauser and Clausing, 1988), needed to be adapted to fruit research and should "provide a science-based methodology for validating and orienting technical research according to societal parameters (consumer demand-related attributes)”.

The method has been described and developed to a quite remarkable extent. It is available to the public for use or further development (see www.isafruit-vdg.ch). At this stage, it can be stated that the House of Quality approach is a dynamic tool to sharpen the focus of our research rather than for applying it each time in the same way like an analytical balance.

Despite the fact that the House of Quality is still very much under construction, and will maintain this status most likely as long as it is used, some more specific conclusions can nevertheless be drawn from the experiences made by ISAFRUIT. Apart from the achievements, these conclusions may provide also a critical look at the tool developed, the cases studied, the potential outcomes and its practical implications.

THE STATE OF THE ART OF THE ISAFRUIT HOUSE OF QUALITY

Applicability of the Tool

To create a simple tool based on an initially quite simple concept proved a challenge, which was to be conquered. The House of Quality-table provides a wealth of information, which seems hard to overlook and appreciate as a whole and difficult to summarize. Therefore, it is actually also quite difficult to draw simple conclusions for practical application in daily product development and production technology research.

Avoiding Disintegration of the Product

The ISAFRUIT House of Quality offers a huge amount of information about consumer demand traits, how these demands relate to technical attributes, and what impact technical experiments deliver to increasing fruit consumption. However, such a structured and atomized way of documenting quality attributes and attitudes makes it difficult to provide a synthesized, integrated view of what wants to be understood and achieved: how an apple best responds to consumer demand being, as it is, a result of complex interactions between behavioral and technical traits. Conclusions capable of addressing reality and creating impact in the real world are difficult to draw from such a disintegrated view. One way to counteract this is to have a look at the roof of the House of Quality. It documents positive and negative correlations between technical attributes. These relations exemplify that an apple is not a disintegrated product represented in a list of attributes that can be reassembled by addressing individual consumer demands. Technical advantages and disadvantages of changing attributes, the extent of a change, and the importance ratings set by consumers have to be carefully reflected and balanced out in order to find best solutions with the potential to create impact. Also, consumer perceptions tend to be very much correlated. Any kind of processing is likely to not only diminish consumer perceptions of naturalness, but also their perception of for instance tastiness and healthiness. Again, the process of discussing these issues seems the most important output of the exercise which can, despite the difficulties, create considerable impact in product and technology development work.

Conceptual Drawback

One chapter in this *Scripta Horticulturae* volume (Bravin et al., 2012) shows that some conceptual drawbacks remain in the actual version of the House of Quality. It was difficult to integrate attributes which relate to farm economy, despite the fact that they are extrinsic quality attributes related with consumer demand and referring to the sustainability of the production system delivering the fruit to the market. Aside from the disintegration challenge mentioned above, this makes clear that there remains scope for a further conceptual development of the ISAFRUIT House of Quality.

Interdisciplinarity

A Prerequisite of Success

It has been outlined in this *Scripta Horticulturae* volume that the development of a House of Quality is indeed an interdisciplinary experience. Or in other words: interdisciplinary cooperation was both a prerequisite and a procedural goal of the successful development of a House of Quality. We discovered that the development of the tool and also its application cannot be a success, if interdisciplinarity is not properly addressed. But how to do this? Interdisciplinarity is not just happening by itself by mere establishment of its need and by jointly describing project goals and expected outputs. Proper communication is a much underestimated key success element, to create progress in interdisciplinary work (see below). The best progress is made in spending time and working together. This can hardly be done by e-mail correspondence, may be supported by telephone discussions but is most productive if physically getting together quite regularly for jointly developing the method.

This fact requires increased attention in applied (horticultural) research since it responds to the need of addressing the systems approach, which is on the strategic research agendas world-wide for improving impact and outcome of research and development activities. In view of this, the ISAFRUIT House of Quality experience was a door opener for many other issues that it was not thought to be at its launch.

The Meaning of Attributes

The exercise to create linkages between technical attributes and consumer demands was the learning step ‘par excellence’ of the Vasco da Gama – process experience in making interdisciplinarity real.

For properly addressing the goals of a House of Quality exercise, the focus needs to be on consumer perception as the principal aspect leading through the process, not on the technical attribute knowledge. The resulting problem in linking consumer and technical sciences under these circumstances happened to be, that there may be discrepancies between consumer reality and technicians views. Furthermore, consumer studies often resulted in qualitative and quantitative findings. How to integrate the qualitative findings into the House of Quality for establishing useful linkages between consumer-related demands and technical attributes?

An example may exemplify this: The consumer meaning of “healthy” does not necessarily correspond with the technical meaning of “healthy”; thus, e.g., the consumer perceives orange juice as being most “healthy”, while on the technical side, it is known that orange juice can contain more pesticides than apples, and may contain sugar to an extent which is not necessarily health promoting. A second example: consumers want apple cultivars of increased crunchiness. Technical scientists address this demand by developing technology which increases the firmness of the fruit flesh. However, it turns out that consumers mean firmness of the peel and not of the flesh since for them "crunchy" is a state defined by the sound while biting into an apple and this is not well correlated with the technical measure of firmness of the fruit flesh.

These two examples show that consumers may make decisions based on *i*) incorrect knowledge, or *ii*) their own meaning of the wording they use, and that consumers (and consumer scientists) might have other demands in mind than those that technical specialists are improving. This requires – in a House of Quality exercise with consumer and technical scientists involved – a great deal of education of both, in both ways, which cannot be achieved without dedication and a considerable amount of discussion time, only achievable at the event of a longer process.

Language and its mental concepts do matter a lot in interdisciplinarity. At the beginning of a project, mutual understanding of the meaning of expressions and mental concepts behind wordings are missing, and scientists do generally not want to "waste" time for a team process at project beginning even if it would be essential for success.

Properly Addressing Communication

How can the communication challenge, described above, be properly addressed? It has been most beneficial in the ISAFRUIT House of Quality experience, to form tandem teams consisting in one consumer scientist and one technical scientist. Defined linkage sectors of the House of Quality were assigned to each team for clarifying the linkages between attributes. Before doing this, several sessions were required to realize that consumer and technical scientists were speaking different languages even if using the same or similar words. Once the tandem teams were formed, the situation improved and progress could be made in developing the House of Quality.

THE POTENTIAL OF THE HOUSE OF QUALITY

The House of Quality – and Quality Function Deployment – methodology has already been proposed for fruit research (see Bech, 2000) as a tool for better addressing market and consumer demands in horticultural research. With the ISAFRUIT-House of Quality exercise, this suggestion has gained momentum.

Research has been a main driver of the development of new horticultural production systems responding to societal demands (e.g., integrated production). It may be expected that the House of Quality-approach provokes a further step in this development and creates impact in the horticultural sector and outcome in society. However, for increasing its potential, the above mentioned drawbacks should be addressed with considerable effort.

If this is true, the approach may complement the actual tripartite sustainability concept (ecology, economy, society, while society has been restricted often to the producing sector) and add a further component: the consumer. Nowadays, it is often asked in agricultural research, what may come "after" integrated or organic (sustainable) production? Why not be a bit visionary: The integration into horticultural research of the principles behind the House of Quality and of the reflections about the production systems of tomorrow could be an essential driver for the development of technically sound production systems which respond to societal demands. May we tentatively call it the SUCO concept (Sustainable, including organic and integrated production, and Consumer-demand driven) or, may be, the RESPECT concept (RESpectful Production – E for ecology and economy – C for consumer demand – T for total quality approach)?

EPILOGUE

Many applied agricultural research projects aim at solving technical problems related to producing goods (e.g., fruit), leading to improved quality and thus, assumingly addressing consumer demands. The ISAFRUIT House of Quality-exercise has resulted in a tool – even though yet quite complex – providing more clarity in whether technical improvements may really address consumer demands and needs. The development process behind the Vasco da Gama-process, was an indeed exciting multidisciplinary experience. We hope that its record, documented in this Volume of *Scripta Horticulturae*, may stimulate further developments to the benefit of a competitive fruit sector and a society increasingly enjoying fruit and its health promoting compounds. System analyses and interdisciplinary work are increasingly required in research for testing and finding feasible, sustainable solutions for problems of our societies. The case presented in this *Scripta Horticulturae* could also be an exemplary learning case for understanding how to more effectively approach interdisciplinary research projects.

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