Searching for a sensory vocabulary for Swedish vegetables

– An exploratory study of the flavour and aroma characteristics of carrot, cabbage and onion

Jenny Arnér

Independent project in Horticultural Sciences • (30 hp)

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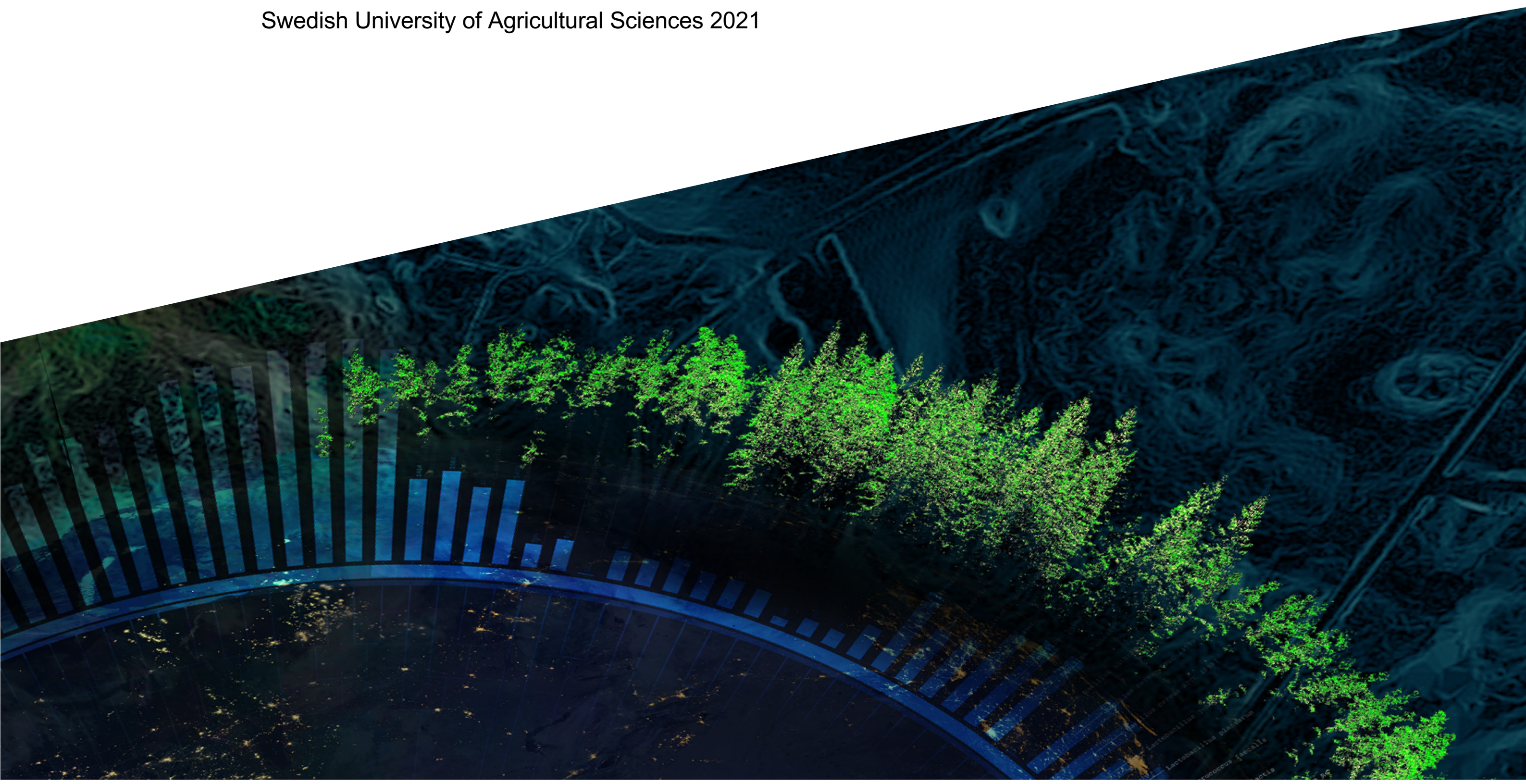

Searching for a sensory vocabulary for Swedish vegetables – An exploratory study of the flavour and aroma characteristics of carrot, cabbage and onion

På jakt efter ett sensoriskt språk för svenska grönsaker- En undersökande studie om smak och doft hos morot, kål och lök

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Abstract

Flavour is an important aspect in the consumption of fruits and vegetables. However, the current regulatory context within EU for the quality of fruit and vegetables involve standards that lay primary emphasis on visual properties but limited focus on flavour and nutrition.

Despite its importance to consumers, the flavour aspect of quality is commonly overlooked. The limited availability and use of a vocabulary hinder a consensus concerning flavour quality within the supply chain as well as to consumers. The present thesis presents the outcomes of the project *A culinary roadmap to Swedish vegetables*. The project was initiated by top chef Daniel Berlin by reason of his experienced challenges to find exceptional and consistent flavour quality in local horticultural products and communicating this aspect of quality with colleagues and suppliers.

A sensory language for fruits and vegetables could be a helpful tool to describe flavour variations. By identifying variations in flavour, the chance to attain customer satisfaction as well as contribute to a consensus within the supply chain may be increased.

The main objectives of the present thesis were to a) examine the flavour and aroma characteristics of cultivars of vegetables which are commonly used in restaurant cuisines, being carrot, cabbage and onion and b) investigate whether consensus can be obtained by a sensory panel with limited training, on the characteristics of the chosen vegetables. Achieving consensus indicates that the perceptions by the panel could act as a guidance of the sensory descriptions. Using a descriptive sensory method, the characteristics and differences in flavour and aroma of heat-treated varieties of carrot, cabbage and onion were examined. Previous studies indicate that the genetic material is one of the most decisive factors for sensory characteristics, which motivated the current study to explore the differences between varieties of vegetables.

The samples were cooked through sous vide technique, which is commonly used in restaurant kitchens. Cooking instructions were given by a chef at the restaurant of Daniel Berlin. This study demonstrated that the chosen method was successful in generating sensory attributes describing flavour and aroma. The results show significant variations in characteristics such as sweetness, nuttiness, perfuminess and fruitiness in cultivars of carrot and within bitterness, freshness, fruitiness in the cultivars of cabbage. Between onion cultivars prominent variations appeared within the characteristics of sweetness, bitterness, freshness, pungency, sulfurous flavour and aftertaste. The key outcome of the study is that significant variations within a part of the attributes in the evaluation was found. This in turn suggests that the perceptions within the panel were partly similar, which in turn implies that a partly consensus was achieved. The common perceptions by the panel on the sensory attributes implies that there is potential for developing a sensory vocabulary for these vegetables.

Keywords: sensory, flavour, quality, vegetable, descriptive, analysis, terminology, vocabulary, marketing, carrot, cabbage, onion, horticulture

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The limits of my language mean the limits of my world

Ludwig Wittgenstein

1. Introduction

In this chapter, the background of the thesis' topic is introduced. Thereafter the objectives and research questions are described, which is followed by a subsection presenting the scope and limitations of the present work.

1.1. Background

The consumption of fruits and vegetables among Swedish consumers do not meet the National Food Administration's (Livsmedelsverket) recommendations of a minimum of 500 grams of fruit and vegetables a day (Swedish board of agriculture 2015).

In parallel, the adopted national food strategy in Sweden aims to contribute to an extended food production for the Swedish as well as foreign markets, corresponding to consumer demands (Government offices, 2016).

Consumer habits and choices related to horticultural products are affected by many factors, such as availability, monetary costs and socioeconomic situation (Pollard et al. 2002; Appleton et al. 2019; Hoppu et al. 2020). In order to increase the consumption of fruits and vegetables, and maybe especially Swedish grown products, in the different customer segments, various approaches are needed.

Currently, international standards and regulations imply that the quality of fresh fruits and vegetables is attributed to freshness and appearance. The products are assessed based on size and shape (Swedish board of agriculture 2012; Kyriacou & Rouphael 2018). The supply chain demands resistant, abundant and homogenous looking products, whereas flavour of fruits and vegetables is an overlooked element in quality standards (Klee 2010; Tieman et al. 2017; Rocha et al. 2013b; Folta & Klee 2016; Kyriacou & Rouphael 2018). Thus, consumers often try to make a less meaningful conclusion of the potential flavour in horticultural products based on their appearance (Sogn-Grundvåg & Østli 2009).

Over the years, dissatisfaction of the flavour in various horticultural products has been raised (Baldwin et al. 2000; Engel et al. 2002; Klee 2010; Nilsson 2012; Nilsson 2014; Rocha et al. 2013; Bartoshuk & Klee 2013; Folta & Klee 2016; Holmes 2017; Tieman et al. 2017; Meny 2018; Appleton et al. 2019; Barber & Ngu 2019; Jörgensen 2019). Focusing on high-yielding and disease-free plants have implied a low priority of flavour within breeding programmes (Kader 2008; Klee 2010; Bartoshuk & Klee 2013; Rocha et al. 2013b; Folta & Klee 2016). The discussion has mainly concerned flavourless tomatoes (Klee 2010; Rocha 2013; Folta & Klee 2016; Holmes 2017; Tieman et al. 2017).

At the same time, sensory quality of fruits and vegetables is mentioned to be of great importance as flavour satisfaction is be key in consumer's purchase decision (Pollard et al. 2002; Engel et al. 2002; Radovich et al. 2003; Barret et al. 2010; Appleton et al. 2019; Spendrup 2020).

Reputable restaurants awarded with Michelin stars in Sweden are visited by both national and international guests traveling far to experience their food. Chefs are constantly searching to find Swedish products with high quality and exceptional flavour. But to find producers and products of horticultural kind that meet the demands of exceptional flavour can however be challenging (Meny 2018).

Several voices argue that flavour of fruits and vegetables should be considered as they reckon that improved flavour could influence food habits and improve the consumption of vegetables (Kader 2008; Gustafsson see Larsdotter 2009; Barber 2014; Klee 2010; Healy 2017; Westling see Renmark 2019; Hoppu 2020).

Flavour in fresh fruits and vegetables is transient and affected by numerous factors which makes obtaining a consistent level difficult. A body of research demonstrate a number of pre- and post-harvest factors which have an impact on obtaining and maintaining optimal flavour (Mattheis & Fellman 1999; Fjelkner-Modig et al. 2000; Gruda 2005; Kader 2008; Wrzodak et al. 2012; Forney 2013; Seljåsen et al. 2013a; Johansen et al. 2016; Hoppu et al. 2020).

Talavera-Bianchi et al. (2010) express the need for appropriate evaluation tools in order to better understand the impact from breeding, growing, harvesting, shipping and storage on the flavour. The authors mean that the sensory vocabulary to describe differences in many vegetables is currently quite general and that a lexicon with a specific terminology may provide a tool for better understanding the flavours present in fresh leafy vegetables.

Flavour of fruits and vegetables are routinely evaluated through instrumental measurements of a few compounds (Mattheis & Fellman 1999; Barrett et al. 2010). To communicate the complexity of flavours complementary tools may be needed.

There are many studies within sensory science developing lexicons and vocabularies for specific products. In regard to horticultural products, tomatoes, peaches, soybean, mushroom, leafy vegetables and leafy brassica have been submitted to studies creating lexicons (Krinsky et al. 2006; Hongsoongnern & Chambers 2008; Talavera-Bianchi et al. 2010; Belisle et al. 2017; Swegarden et al. 2019; Chun et al. 2020). The obtained lexicons are however rarely applied in the supply chain or in communication towards consumers. In Sweden, the number of conducted studies on Swedish fruits and vegetables is few. Apples, leafy greens, peas, onion and potatoes have been studied (Swahn et al. 2010; Öström & Nielsen 2010; Larsson & Swahn 2011; Gustafsson 2014; Öström & Westling 2015a, Öström & Westling 2015b).

Within the market of wine and beer, a well- established sensory vocabulary for flavour and aroma is used. A comprehensive work of linguistics, sensory and marketing allows producers, suppliers and consumers to share a common language describing sensory characteristics. This creates conditions for a facilitated communication and a consensus in terms of flavour quality (Herdenstam et al. 2009; Jürkenbeck & Spiller 2021).

The wine labels show an example of sensory marketing, which aims to evoke consumer's interest by describing the product's sensory character. Studies have shown that sensory descriptions improve sales and also expectations related to food

(Wansink et al. 2001; Dimara & Skuras 2005; Krishna 2011; Swahn 2011; Swahn et al. 2012; Gustafsson 2014; Turnwald et al. 2019; Jürkenbeck & Spiller 2021).

As flavour is an important variable for chefs and for consumers, the use of sensory descriptions to horticultural products could bring advantages for both producers, supply and retail (Swahn et al. 2010, 2012; Turnwald et al. 2019; Spence 2020; Jürkenbeck & Spiller 2021). They may highlight existing potential and the gastronomic diversity in Swedish products, improving consumer quality awareness. (Swahn 2011; Gustafsson 2014; Westling see Renmark 2019; Jürkenbeck & Spiller 2021).

Against the background of the sensory language in the wine market, a joint view upon flavour quality by using a common vocabulary might contribute to added value to horticultural products and simplify communication between producers, suppliers, retail, chefs as well as consumers. Due to the limited knowledge concerning flavour of horticultural products and a limited vocabulary to describe it, a consensus on the subject is hindered between members of the supply chain.

For restaurants working with horticultural products, satisfying flavour quality might be a considerable means of competition. Currently, chefs experience difficulties to find as well as define what flavour quality they seek in vegetables.

In 2019, top chef Daniel Berlin turned to The Swedish University of Agricultural Sciences (SLU) with the wish to work towards improved flavour quality of Swedish horticultural products. He experienced difficulties to find vegetables with satisfying as well as consistent flavour quality. He expressed challenges with the limited tools to describe the characteristics of the products in a manner that suppliers and colleagues understand.

Based on the problem described by Daniel Berlin, the project "*A culinary road map for Swedish vegetables*" was started to explore the sensory characteristics of three commonly used vegetables.

This thesis presents parts of the conducted sensory study within the project and is completed with a literature review.

1.2. Aims and Research questions

As flavour is an often-overlooked quality aspect within the supply chain of horticultural products, the aim of the current study was to contribute to raised awareness and understanding on the subject of flavour of these products, through an exploratory study.

The aims of the current thesis were to present the outcome of the study within the larger project and describe the use of sensory science to generate a sensory vocabulary as well as to explore the potentials of addressing and describing flavour in fruits and vegetables.

The objectives of the practical part of the current study were a) to examine the flavour and aroma characteristics of cultivars of vegetables often used in restaurant cuisines and consumers kitchen, being carrot, cabbage and onion and b) to investigate whether consensus can be obtained by a sensory panel with limited training, concerning the characteristics of the chosen vegetables. Achieving consensus indicates that the perceptions by the panel could act as guidance of the sensory descriptions.

To achieve the objectives, the study aimed to answer the following questions:

- Is it possible to attain sensory attributes to describe the flavour and aroma of heat-treated carrot, cabbage and onion by using a sensory panel with limited training?
- Are there differences in flavour and aroma between cultivars of carrot, cabbage and onion?
- Is it possible to achieve consensus within a panel with limited training concerning the characteristics?

1.3. Scope and limitations

This thesis is based on a notion that flavour is an overlooked quality aspect that should be increasingly considered among fruits and vegetables. A flavour focused approach could be one among numerous tools to achieve a higher demand for Swedish horticultural products, which may contribute to an increased production among Swedish producers, in line with the national food strategy.

Practical limitations
Limited economical resources within the project *A culinary roadmap to Swedish vegetables*, which also acts as the experimental part of the present thesis, entailed that the sensory evaluation was made as an exploratory study. Hence, the results should be viewed accordingly.

The circumstances allowed a limited number of hours for panel training and analysis was limited to involve three vegetables; carrot (*Daucus carrota*), cabbage (*Brassica oleracea*) and onion (*Allium cepa*), with few cultivars of each.

The results in this thesis focus on the outcomes of the analysis of flavour and aroma characteristics.

Literature limitations
The reviewed literature cover articles within the disciplines of biology, horticulture as well as sensory science, of which the sensory science refer to the area of food and meal science. The focus of the present thesis entails that the senses of taste and smell is highlighted, while sight, hearing and touch is only briefly mentioned.

2. Literature Background

In this chapter findings from the conducted literature review are presented. The section aims to present an overview that allows an increased insight to the challenges in obtaining and maintaining flavour quality in fruits and vegetables as well as to give a brief introduction to sensory science and its application within food.
Herein, consumer demands and quality standards of horticultural products are described. The following subsections describe the various factor's impact on the flavour of fruits and vegetables and the discipline of sensory science and sensory analysis. The chapter then finish with presenting potentials of using sensory marketing to fruits and vegetables and the advantages of describing their flavour.

2.1. Consumer demands

In Sweden, the consumption of fresh fruit and vegetables per person has increased by about 30 and 170 percent respectively since 1960 (The Swedish board of agriculture 2015). The direct consumption per person amounts to 160 grams of vegetables and 200 g of fruit a day and refer to purchased amounts including inedible parts. Hence, the consumption does not meet the National Food Administration's recommendations of eating 500g a day (The Swedish board of agriculture 2015).

A number of factors, such as culture, socioeconomic situation and price influence food choices in relation to fresh fruits and vegetables (Pollard et al. 2002; Cox et al. 2012; Appleton et al. 2019; Hoppu et al. 2020). Consumer views upon horticultural products vary and it is challenging to entice them in a way that covers over all types of consumer segments.

A number of studies however demonstrate that flavour is one of the most influential factors determining eating behaviour (Pollard et al. 2002; Radovich et al. 2003; Barrett et al. 2010; Spendrup 2020). Satisfactory flavour is crucial whether the consumer will buy it again, while unappealing flavour may affect the consumption negatively (Pollard et al. 2002; Engel et al. 2002; Cox et al. 2012; Appleton et al. 2019; Hoppu et al. 2020; Jürkenbeck & Spiller 2021).

In a study by Spendrup (2020) consumers considered flavour to be the most determining factor at the purchase of fruits and vegetables, followed by locally produced. Consumers also rated flavour as the second most important aspect to consider in breeding of crops. The same study found that Swedish growers forecast a continued demand on flavour quality from consumers (Spendrup 2020).

350 Swedish food producers in agriculture and horticulture took part in a survey where almost 9 out of 10 (87 percent) stated flavour to be very important when developing their products. According to the same survey, 7 out of 10 (71 percent) producers experience flavour to have become more important to consumers in recent years (LRF 2016). In a survey among organic farmers in the U.S., flavour was rated as the most important trait to consider in deciding which variety to grow. Many of the participants sell direct to consumers and know that if the buyers don't like it, it doesn't matter if the plant is resistant to pests or frost (Healy 2017).

More than 450 national and international chefs and leading persons in the restaurant industry rated taste as the most inspiring factor while quality and sustainability were on the second and third place respectively (ICA 2018).

Consumers spend increasingly amounts of money in visiting restaurant, where multisensory experiences as well as exceptional flavour is essential. Many of the trends in restaurants strive to optimize flavour in one way or another (ICA 2018). Styregård (2020) and Klee (2010) highlights the role of the chefs as they are an important link between producers and guests (Beans 2017).

One occurring trend, *From farm to flavour* involves strengthening collaborations between chefs and growers in order to shorten the distance between the two. The aim is to obtain optimal flavour and character through adjustments of cultivation and harvest. Another established trend is serving dishes that highlight the pure and unique flavour of a certain product, through careful processing and cooking.

An example of the constant search for high flavour quality among chef is the project *Exceptionell Råvara* (Exceptional Product) that started in 2011 by top chef Björn Frantzén. The project sprung from the wish among Swedish chefs to simplify the search for products with exceptional quality (Meny 2018). The project aimed to allow discussions and collaborations between chefs and producers to obtain exceptional products that meet the demands of restaurants. Before the association, there was no natural meeting place for chefs and producers to discuss quality and flavour (Exceptionell Råvara n.d.).

Another project aiming to contribute to the subject of improved flavour is *Tala Smak* (Speaking of Flavour) that was initiated by Sigill Kvalitetssystem AB White Guides ABThe overarching goal is to develop a systematic food language, which can be understood and used by producers, retailers, chefs as well as consumers. The project aims to develop, establish and quality assure a set-up for evaluation of taste, taste experiences and sensory quality (Tala Smak 2021).

Looking internationally, one of the most prominent persons on the restaurant scene with a flavour focused approach is the reputable top chef Dan Barber, owner of *Blue Hill Restaurant* and *Blue Hill at Stone Barns* in New York. He has been an advocate to sustainable fine dining as well as a ground-breaking voice in questioning the traditional selection for high yielding and good- looking crops (Barber 2014). He is famous for his eager to develop vegetables with the best possible flavour, in order to entice more people to choose vegetables (Healy 2017; Barber & Ngu 2019).

2.2. Quality

The matter of quality is complex and encompass several aspects. In regard to fresh fruits and vegetables, a universal definition of quality is barely possible due to the supply chain's numerous stakeholders with differing perspectives.

Most commonly, quality refers to food safety, shelf life, nutritional value and sensory aspects (Barrett et al. 2010; Rocha et al. 2013b; Seljåsen 2013a). However, the regulations within European Union (EU) wherein the official criteria for quality of fresh fruits and vegetables are defined, fail to address complex aspects such as sensory and nutritional values (The Swedish board of agriculture, 2014; Kyriacou & Rouphael 2018).

2.2.1. Quality Standards

Within EU, regulations for quality grades and standards for evaluation of food products have been established (The Swedish board of agriculture 2012).

The regulations facilitate product standardization and can be seen as a set of parameters that form a classification system, based on quantifiable properties. The standard acts as product description with a clearly defined content and address aspects that are of interest to members of the supply chain-, in regard to fruits and vegetables uniformity of size and shape, freshness and absence of defects are prioritized (The Swedish board of agriculture 2014).

Since 1995 the Swedish board of agriculture control the compliance of the standards in Sweden (The Swedish board of agriculture 2012).

Regulations adopted by the EU are based on the Codex Alimentarius by the Food and Agriculture Organization (FAO) of the United Nations. They differ in the sense that EU standards are mandatory, while UN standards are applied on a voluntary basis (The Swedish board of agriculture 2003).

One outgrowth of the mandatory quality standards is that products not meeting the strict criteria, but of which the market actually demands, may be prevented from being traded and returned to producer. This may cause food waste which has been reason for discussion (SVT Nyheter 2006; Kihlberg 2014; Nilsson 2014; The Swedish board of agriculture 2014).

A common misconception is that the standards exists to protect consumers from deficient products, however, the actual main purpose is to facilitate professional trading along the supply chain as the product description simplifies for buyers and sellers, owe to the fact that the specification and minimize the risk of misunderstandings (The Swedish board of agriculture 2014).

The standards continuously change with the market, based on the views and opinions of producers, suppliers and retail. The perspective of the consumer is however less represented in the formation of the standards.

2.2.2. Flavour - an overlooked quality aspect

In regard to consumers acceptance and expectations of fruits and vegetables, visual cues are important and should not be underrated (Hoppu et al. 2020). However, there are indications that the official quality criteria of horticultural products and the aspects that consumers and chefs find relevant is in discrepancy.

The discussion concerning poor flavour quality of fresh fruits and vegetables, tomatoes in particular, has been addressed repeatedly by researchers as well as consumers (Baldwin et al. 2000; Engel et al. 2002; Klee 2010; Nilsson 2012; Nilsson 2014; Barber 2014; Rocha et al. 2013; Bartoshuk & Klee 2013; Folta & Klee 2016; Holmes 2017; Beans 2017; Tieman et al. 2017; Appleton et al. 2019; Meny 2018; Barber & Ngu 2019; Hoppu et al. 2020).

Assessment of flavour of horticultural products is foremost conducted on fruits, through instrumental measurements of the sugar/acid ratio as it is an indication of the overall sensory quality and correlated to consumer acceptance (Kader 2008). The instruments are superior in routine handling but do not capture the complex flavour characteristics since a number of other compounds like non-volatiles and aroma volatiles also contribute to flavour (Mattheis & Fellman 1999; Kader 2008; Barrett et al. 2010). Thus, conclusions should be drawn with care from that type of measurements.

Hoppu (2020) suggests that flavour in fruits and vegetables should be considered and Kader (2008) and other researchers argue that improved flavour could influence food habits and improve the consumption of vegetables (Kader 2008; Gustafsson see Larsdotter 2009; Klee 2010; Healy 2017; Westling see Renmark 2019).

Reasons for the decline in flavour quality have been widely discussed during recent years and an often- accepted explanation to the decline in flavour is that breeders have focused on parameters such as pest resistance and shelf life to meet the demands of the industry, which has become to the expense of flavour (Baldwin et al. 2000; Folta & Klee 2016; Tieman et al. 2017; Klee 2010; Bartoshuk & Klee 2013). The strive towards breeding in line with the supply chain’s objective was not intended to imply loss of flavour. As breeders focused on improving yield, other genes may have been lost and with time, the accumulating losses add up to a big decrease in flavour (Folta & Klee 2016; Holmes 2017, Tieman et al. 2017).

Obtaining satisfying flavour is complex and onwards breeders need more knowledge and improved tools to be able to have a flavour focused approach in commercial varieties (Kader 2008; Tieman et al. 2017; Klee & Tieman 2013).

In parallel, as will be discussed in the next chapter, cultivation and post-harvest handling also influence flavour and the practices could to a greater extent be adjusted on the basis of flavour rather than appearance.

2.3. Flavour of fruits and vegetables

The taste and aroma of fruits and vegetables is dependent on a line-up of volatile and non-volatile compounds. The non-volatiles refer to sugar, acids and phenolics which form the taste, whereas the aromas are derived from volatile compounds such as esters, aldehydes, ketones and alcohols. (Kader 2008)

The flavour quality of various horticultural products is to a large extent dependent on its genetics, but several studies show that factors and circumstances during cultivation and post-harvest also influence flavour.

2.3.1. The role of cultivar

Genetic material has a major influence on the sensory and physiochemical of fruits and vegetables (Mattheis & Fellman 1999; Baldwin et al. 2000; Gruda 2005; Seljåsen 2013a). Hence, cultivar selection suitable for the climate and cultivation conditions is of great importance to ensure internal as well as external quality.

Over time, the seed supply has become increasingly homogenized (Khoury et al. 2014). FAO estimates that the crop diversity decreased by 75 percent during the twentieth century (FAO 2010). At current, the global seed supply is controlled by few companies on the market which entails a narrow selection (Nilsson 2016). Swedish breeding programmes of kitchen crops ended due to the increasing competition of hybrid production abroad (Spendrup 2020). Today Swedish growers are mainly dependent on internationally bred crops.

In a changing climate, a decreasing genetic material risks to lead to increased vulnerability in food security (Khoury et al. 2014). Therefore, biological diversity should be considered as a life insurance and essential to maintain. The loss of crop diversity entails a loss of diversity in flavour, too (Jewert 2012; Barber & Ngu 2019).

Some plant breeders take a political stand against the corporate control of seeds by breeding for organic cultivation and focusing on flavour (Healy 2017).

New approaches in crop breeding turn attention from yield and involves analysis of consumer preference (Rocha et al. 2013; Folta & Klee 2016). In parallel, increasing number of studies are made to develop lexicons and sensory profiling intended to serve as a tool to an improved understanding of the variations among crop varieties (Talavera-Bianchi et al. 2010; Rocha et al. 2013b; Belisle et al. 2017; Swegarden et al. 2019).

Initiatives to reverse the trend of decreasing crop diversity are taken such as supporting small-scale seed companies as well as collecting seeds and plant material from landraces in gene banks. Landraces are valuable in that they bring both properties suitable for sustainable agricultural cultivation systems and gastronomic properties (Sans et al. 2018; Westling et al. 2019).

Another innovative approach in order to bring a diversity of flavours into plant breeding is to allow chefs to lend their experienced palates (Rocha et al. 2013b; Beans 2017; Healy 2017). Breeders might care for flavour but do not have recourses to select for it (Beans 2017). By involving chefs that are used to describe flavour, the selection can be simplified, and time can be saved (Beans 2017).

The Culinary Breeding Network (CBN) and *Seed to kitchen Collaborative* (SKC) are examples of initiatives building networks of plant breeders, seed growers, farmers and chefs to develop vegetable varieties with superior culinary qualities. The idea is to create conditions for exchanging knowledge through identifying desirable varieties for both chefs and growers and the approaches vary from informal conversations to research analysis (Beans 2017). Formal taste tests of prepared crops that reflect how they might actually will be eaten are arranged, to allow local farmers to learn what chefs want.

Already mentioned top chef Dan Barber was one of the first to acknowledge the power of these networks. In 2013 he initiated collaborations of chefs, farmers and breeders to identify or even develop varieties that benefit the grower and the consumer.

Dan Barber's partnership with breeders did later lead to the seed company *Row 7 Seeds* that is exceptional in breeding for flavour. *Row 7 Seeds* supplies seeds to international restaurants and growers, of which the Swedish restaurant *Daniel Berlin* was one (Row 7 Seed n.d).

2.3.2. Impact of pre- and post-harvest factors

Pre harvest factors

Environmental factors (such as soil, climate, sunlight, temperature and precipitation) and cultural practices (fertilization, cropping, pest control and cultivation system) have been found to influence the flavour of various horticultural crops (Hårdh et al. 1977; Mattheis & Fellman 1999; Rosenfeld et al. 2002; Gruda 2005; Kader 2008; Seljåsen et al. 2012; Seljåsen 2013a; Johansen et al. 2016; Hoppu et al. 2020).

Seljåsen et al. (2013a) concluded that climate factors were, after variety, the second most important factor having an impact on sensory quality of carrots. Concentration of terpenes, carotenoids as well as perceived sweetness and harsh flavour differ between carrots grown in differing environments (Seljåsen et al. 2013a). In a study of onions, season was found to be the most significant source of variation in pungency between cultivars (Hamilton et al. 1996 see Mattheis & Fellman 1999).

Results by Hårdh et al. (1977), Mølmann et al. (2015), Johansen et al. (2017) show a difference in sensory characteristics in different vegetables along various latitudes. Carrots grown in northern latitudes showed the highest score for sweetness compared to those grown in lower latitudes (Rosenfeld et al. 1997).

The study by Johansen et al. (2017) on broccoli also demonstrated a distinct impact on sensory quality from the interaction of temperature and light conditions.

The influence of crop nutrition has been subject for several studies (Mattheis & Fellman 1999; Seljåsen et al. 2012, 2013a). In onions, the level of tear producing precursors were found to increase with increased sulfur availability (Randle 1997, see Mattheis & Fellman 1999). In a study made on carrots, reduced nitrogen input was found to increase bitter flavour (Sorensen 1999; Paoletti et al. 2012 see Seljåsen 2013a). By contrast, Schaller, R. G. and Schnitzler (2000) found carrots to taste less bitter and earthy, but more intense and sweet with reduced nitrogen input (Schaller, R. G. and Schnitzler 2000 see (Kjellenberg 2007).

The impact from cultivation systems have been studied by Fjelkner-Modig et al. (2000) and Zhao et al. (2007) that both obtained results not indicating any significant differences in sensory quality between vegetables grown organically and conventionally. Although, Haglund et al. (1998) found organic carrots to have a higher intensity of bitter taste compared to conventionally grown carrots.

Stress

Various practices along the supply chain risk to induce different types of plant stress. Plant stress may activate physiological and molecular mechanisms within the plant and secondary metabolites may be synthesized in order to adapt to the suboptimal circumstances (Bennett & Wallsgrove 1994). Secondary metabolites in vegetables are be appreciated as bioactive compounds like terpenes and carotenoids (in carrots), glucosinolates (in brassicas) and polyphenols (in onion and red cabbage) (Gruda 2005).

Plant stress can have an effect on functional, physiochemical and sensory qualities and recent research has shown that the biosynthesis of some odorants and flavours might be controlled by genes whose expression is altered or induced by biotic or abiotic stresses (Klee 2010; Wüst 2018).

Mechanical damage may harm an protective outer layer and induce a stress response, which in turn can affect quality and result in strong off flavours. Newly harvested carrots exposed to mechanical stress was found to lead to 30% reduction in sweet taste and increased flavour intensity of ethanol and sickeningly sweet taste (Seljåsen et al. 2013a). For example, Seljåsen et al. (2013b) found that the increased bitter taste occasionally occurring in organic crops may be explained by an increase in psyllid attack- resulting in synthetization of bitter compounds.

Harvest

Maturity at harvest is according to Kader (2008) suggested to be one of the most important factor in flavour of fruits as aroma and flavour is dependent on development and ripening. Sugar, which is a common component of taste and converted into other compounds contributing to flavour, is provided as long as the fruit remains on the plant (The Swedish board of agriculture 2003).

The demands of the market commonly imply fruits to be harvested previous to optimal ripeness due to the fact that time of harvest manipulates shelf life and optimize market life (Kader 2008). An early harvest ensures the product (most commonly fruit) being firm enough to handle but comes at the expense of flavour. Due to low sugar and reduced ability to produce aroma volatiles in many cases, immature fruit may never develop optimal flavour (Mattheis & Fellman 1999; Kader 2008; Forney 2013).

Depending on type of fruit, the flavour development varies after harvest; climacteric fruits harvested at physiological mature stage may develop flavour through post-harvest ripening while non-climacteric fruits, including all vegetables derived from non-reproductive organs, have limited post-harvest flavour development (Mattheis & Fellman 1999).

Post-harvest

After harvest, the quality deteriorates at a rate determined by respiration and transpiration (The Swedish board of agriculture 2003). Through actions that slow down metabolism and reduce dehydration, post-harvest handling shall inhibit decay and maintain acceptable quality (The Swedish board of agriculture 2003).

The composition of volatiles and non-volatiles change depending on physiology of the product and post-harvest conditions, such as temperature at storage as well as in retail (The Swedish board of agriculture 2003). Also, relative humidity, ethylene levels and the oxygen and carbon dioxide balance are of importance (Forney 2013; Seljåsen et al. 2013a).

Loss of flavour is often due to a reduction of sugar, acids and aroma volatiles but may also be caused by development of off flavours (Kader 2008; Forney 2013).

The two primary mechanisms of flavour change in fresh produce after harvest are metabolic and diffusional (Forney 2013). External circumstances like handling and storage environment as well as internal process and ripening during post-harvest have a varying impact on these processes.

Diffusional changes refer to volatile's ability to be lost or mass transferred through diffusion, in or out of the product. Diffusion is determined by the compound's volatility, concentration gradient and barriers surrounding the product. Mechanical damages or cutting are examples of barrier damage affecting diffusion. The concentration gradient is affected by packaging and storage atmospheric conditions (Forney 2013). Unwanted compounds may also diffuse into the fresh produce, resulting in off- odours which may derive from other produce, surrounding environment or packaging material (Forney 2013).

Metabolic changes involve synthesis and catabolism of flavour compounds, or production of off-flavours, which is dictated by respiration and maturity that in turn influence volatile and non-volatile flavour compounds (Forney 2013). The nature of the product being climacteric or non-climacteric is decisive in this matter.

Temperature has a considerable impact on the produce's metabolic activity, which in turn control synthetization and catabolism of flavour compounds. Correct temperature during storage is thereby essential to reduce the risk of causing stress to horticultural products which may speed up deterioration (The Swedish board of agriculture 2003). Increased temperature correlates with increased compound volatility, that might entail flavour loss (Forney 2013).

Examples of actions that slow down respiration and improve shelf life is storage in modified atmosphere (The Swedish board of agriculture 2003). Lower levels of oxygen (O_2), or elevated carbon dioxide (CO_2), reduce the rate of senescence and ripening which prolongs the period of consumer acceptance (The Swedish board of agriculture 2003). Although, when fruits and vegetables risk to be exposed to damaging levels of O_2 or CO_2, anaerobic metabolism may be induced and accumulation of acetaldehydes and ethanol can occur, forming off flavours (Forney 2013).

In carrots, anaerobic conditions increased the intensity of sickeningly sweet taste and ethanol flavour after 10 days of low O_2 concentration (Seljåsen et al. 2013a). The risk of damaging low levels of O_2 should also be considered in packaging, in order to avoid anaerobic respiration (Forney 2013).

Ethylene is a naturally occurring plant hormone that can be used through exogenous application to speed ripening (The Swedish board of agriculture 2003). Ripening induce development of flavour compounds, while low levels of ethylene inhibit development of aroma volatiles. However, increased levels of ethylene in storage of carrots has been shown to cause reduction in sugars as well as 30% increase in bitter flavour, compared to carrots stored in air (Seljåsen et al. 2013a).

2.4. Sensory Science

Sensory science is a multidisciplinary field comprising measurement and interpretation of human responses to product properties as perceived by the senses sight, smell, taste, touch and hearing (Gustafsson 2014).

Humans have always relied on their senses and are constructed to use them to evaluate surroundings as well as foods. In daily life people may often be unaware of how their senses and minds interact to collect and process stimuli and information.

Sensory science can be applied in analysis in order to investigate whether the product's sensory characteristics correspond to consumer preferences (Gustafsson 2014). A major part of sensory involves describing sensory experiences with communicative words and descriptions. The primary reason is to facilitate the communication of the product's characteristics between producers and product developers and occasionally to consumers (Gustafsson 2014).

To achieve scientific results from sensory science and analysis, it is important to possess knowledge on the complexity of the integration between the senses and the surrounding's effect on our interpretation of a context.

2.4.1. The human senses

Physiology

The human senses refer to a physical part including receptors and nerve impulses from stimuli, and a psychological process which transforms the nerve impulse to information placed in a context among our memories and previous experiences (Gustafsson 2014).

The sensory organs possess different types of receptors and react to different types of stimuli. Smell and taste are often referred to as the chemosensory system (Hermansson 1999). The sense of smell is able to detect a high number of odorants while the taste buds may perceive the five basic tastes: sweet, sour, salty, bitter and the recently described taste umami (Gustafsson 2014).

In order to experience taste, taste compounds have to be dissolved in the saliva and come in contact with the chemoreceptors on the taste cells, which are grouped together forming the taste buds in various papillae on the tongue. Further, nerve impulses are passed to the brain (Hermansson 1999). While taste refers to the actual stimuli on the taste buds, flavour is more of a sensory experience where the aromas add a more diverse experience to the taste perception.

The sense of smell registers volatile substances in gaseous form, soluble in water or fat (Hermansson 1999). When odorants stimulate the receptors on the olfactory sensory neurons, a signal is transferred to the olfactory bulb (Gustafsson 2014).

Perception and Cognition

At the store, consumers look, feel and maybe even smell to determine the quality of a fruit (Sogn-Grundvåg & Østli 2009). The way a certain food product smells, taste and appear play an essential role in the way it is experienced and so, consumers decide whether to buy it again or not (Gustafsson 2014).

Many people have learned to assess a fruit based on if the peel is shiny or shrivelled- hence the impression of the fruit is dependent on knowledge and emotional perspectives derived from cultural and psychological factors. Cultural ideas and other conceptions have an impact on liking and preferences of food which unconsciously creates expectations (Gustafsson 2014).

The senses collect information about the food's sensory properties and the surroundings and transfer the information to our central nervous system where it is interpreted, and subsequently creates an overall quality impression. This is referred to as perception. The perception creates a complex picture, and awareness of, the experience of eating (Gustafsson 2014). The brain helps to interpret sensations and by doing so, other factors than the actual taste affects the eating experience (Gustafsson 2014).

Bschaden et al. 2020 studied the impact of lighting and table linen on the intake and taste perception of tomato soup and found that participants ate various amounts and rated the food differently depending on the light conditions. Creating multisensory eating environments to promote vegetable choice and consumption deserves to be studied further, according to Hoppu et al. (2020).

2.4.2. The hierarchy of the human senses

There are indications of there being a hierarchy of the senses and this has a history going far back in time. A large part of the commerce today attracts consumer through sensory expressions and may often inspire to overconsumption (Lönn 2019; Styregård 2019). In parallel, some cultures dismiss the senses as a means of collecting information and knowledge, with the exception being the sense of sight (Lönn 2019).

Most of our impressions are based on vision and sight is often considered to be dominating sense (Hutmacher 2019). Ocular centrism illustrate that sight is privileged over other senses and as a phenomenon mainly encountered in western societies (Hutmacher 2019). For example, most science in the western world is explained or illustrated by formats requiring vision (Hutmacher 2019; Lönn 2019).

When people are asked what sense they would be prepared to do without, smell comes at the top of the list and sight at the bottom (Hutmacher 2019; Vroon 1997). Vision is often considered to act as our higher sense, whereas smell and taste are said not to function with the same accuracy from person to person (Larsson & Swahn 2011).

The vision also has a pronounced role in human's judgment of appearance and colouring of food (ripening fruit reveals information about its state). Sight often triumphs our sense of smell when choosing to trust labelling and expiration date of food products, before making a judgement based on smelling it.

According to some historians sight was considered as the higher sense even in ancient Greece (Söderlind 2021). Explanations for this to have taken shape are several. Smell, as well as touch, has been seen as senses grounded in the body, and of animalistic dimensions, while sight has been considered as a sense connected to the brain and reasonable thinking. With the perspective that human and society rose from a primitive nature, towards a modern culture, allowed the sense of smell to be devalued (Lönn 2019). Hutmacher (2019) discusses that the signs of a universal hierarchy of senses may in fact be culturally and socially reinforced, not a law of nature.

Estimating the role of the sense of smell, historically and in present time, is difficult- partly because most people are insufficiently aware of its importance. Its primary function is to detect danger- which is crucial for animals but plays a minor role to humans in a civilized time.

The functions and processes of sense of smell is vaguely understood (Can 2021). In fact, it is said that the research is 80 years behind that on sight and hearing (Söderlind 2021). The research is complicated by the differences in people's sensitivity to fragrances as well as due to aromas being difficult to quantify, preserve, as well as transfer to electronic media (Can 2021).

However, understanding of the importance of the research on the sense of smell has improved after the outbreak of Covid-19 (Can 2021). One of the common symptoms of Covid-19 is the condition of anosmia, which is loss of the ability to detect smells. The fact that a numerous people suddenly live without a sense of smell has evoked discussions whether its lower status really is entitled (Lönn 2019; Can 2021; Söderlind 2021).

Taking part in testimonies from anosmic people clarifies that losing the sense of smell makes everyday life existentially challenging. Smell plays a significant part in many psychic processes, behaviour patterns and affects motivation and memory (Vroon 1997). Lastly, smell is essential for the sense of taste.

The sense of smell is unique in the way that the aroma stimuli transfers directly to the limbic part of the brain without switching in the thalamus. The limbic part of the brain is characterized as the place where emotions are created and consequently, some scents evoke strong emotions and associations (Bartoshuk & Klee 2013; Gustafsson 2014). This implies that a large part of our emotions during a day are evoked by fragrances (Söderlind 2021).

Studies show that anosmic people risk to suffer from depression, social anxiety and isolation (Söderlind 2021). The risk of suffering from depression when losing smell is even higher than that of becoming blind (Can 2021).

The philosopher Caroline Korsmeyer argues that experiencing aromas and flavours are relevant for a good life, which is reason for them to not be marginalized but get the attention they deserve (Korsmeyer 2005 see Styregård 2020).

2.4.3. Sensory Analysis

Sensory analysis, also called sensory evaluation, use experimental design and statistical analysis for the purpose to evaluate consumer's sensory response towards various products (Hermansson 1999). Sensory evaluation with a food focus has been defined as 'a scientific method used to evoke, measure, analyse and interpret those responses to products as perceived through the senses of sight, smell, touch, taste and hearing' (Lawless & Heymann 2010).

Sensory evaluation serves as an analysis tool within product development, quality control and marketing, most commonly within the food industry and occasionally in dining experiences (Gustafsson 2014). The analysis tracks sensory characteristics, intensity and relative proportion of an evaluated product and generates a sensory profile with attributes that facilitates the dialogue between product developers, production and marketing and in some cases even towards consumers (Hermansson 1999). Attributes refer to the words used in analysis that describe the characteristics of a product. For example bitterness, nuttiness or floral.

The widest application of sensory analysis is perhaps within the wine market. Sensory descriptions are well established for wines and essential for anyone involved in the production, distribution and sale (Herdenstam et al. 2009; Dimara & Skuras 2005). The Swedish alcohol retail monopoly *Systembolaget* conduct sensory analyses of their products primarily in order to communicate towards consumers as a way of increasing the chance for consumer satisfaction.

Sensory analysis use panellists as instruments. By using standardized methods, trained panellists and appropriate laboratory venues an objective analysis with scientific standards may be achieved (Hermansson 1999).

The panellists are commonly screened on the basis of their ability to identify aromas, perceive low concentrations of taste as well as to verbalize the perception and then repeat the assessment with same results (Gustafsson 2014).

An analytical panel is trained in order to express the differences and similarities between samples but may not answer whether the product is perceived as positive or negative. This type of question is better suited for consumer panels which are not trained. Consumer panels are not suited to describe sensory properties, since they don't share the same references and language (Gustafsson 2014).

Sensory evaluation is divided into *analytical tests* and *affective tests* (Lawless & Heymann 2010). An appropriate selection of method is important in obtaining the desired sensory information. There are different types of tests within each division.

Analytical tests use a trained panel as an instrument and focus on measurement and quantification of the product's sensory attributes. The tests aim to collect objective information about the product (Gustafsson 2014). Whereas, *affective methods*, also called consumer testing, focus on consumers perception of the product and studies how likely the product is to be accepted. Affective tests require a large number of participants (Hermansson 1999).

By performing both methods as complement one may answer what type of sensory profile that is preferred by consumers.

Analytical methods divide into two categories: *Discrimination testing* and *Descriptive analysis*. *Discrimination testing* aims to determine whether there is a detectable difference between products, but do not quantify or describe any differences (Gustafsson 2014). The technique may be applied in order to test a product's shelf life.

Descriptive analysis is comprehensive in that it yields deep information about the product and is often applied within food science and industry in order to identify a broad spectrum of sensory attributes and exhibit variations between products (Lawless & Heymann 2010).

The attributes obtained from descriptive tests can be used to formulate a product's sensory profile which in a clear way illustrate the sensory characteristics of food products. These are terms enabling communication to product developers and marketing. The sensory profiles can also be used towards consumers. In the context of crops, sensory profiles may serve breeders a greater understanding of differences between cultivars (Hampson et al. 2000; Rocha et al. 2013a; Belisle et al. 2017).

Commonly used descriptive methods are Quantitative Descriptive Analysis (QDA) and Repertory Grid Method (RGM) (Lawless & Heymann 2010).

QDA was developed with the initial intention to deal with poor statistical treatment on data obtained from already existing descriptive methods such as Flavour Profile (Stone et al. 1974). QDA is suitable for measuring sensory characteristics and can be a tool to identify which sensory attributes are important to acceptance for consumers in an additional study. The method engages a trained panel, by contrast to RGM that uses untrained consumers.

As a mean of quantifying sensory perception, the panellists fill in score sheets with attributes and continuous line scales (Gustafsson 2014). During analysis, panellists measure sensory intensities independently, using the scale to determine the sensory intensities. Consequently, the difference among products produced by QDA will be a relative measurement (Lawless & Heymann 2010).

The scales allow the use of standard statistical procedures such as multivariate analysis of variance, principle component analysis (Lawless & Heymann 2010). RGM is commonly used in investigations aiming to develop a vocabulary for food products (Swahn et al. 2010). The method studies consumer perception of products through one-to-one sessions with a panel leader which demands much time (Gustafsson 2014).

2.5. Describing flavour in marketing

Today food is considered as more than just nutrition. Consumers buy identity and lifestyle through their purchase decisions.

The grocery store is filled with hundreds of products, and the consumers need guidance and motivation in order to choose a particular product- and the ways of doing so are many.

The ocular centrism previously mentioned is obvious in marketing as well. Most marketing strategies appeal to the sense of sight- with colours and logotypes and slogans, while it is rare to see marketing addressing other senses (Krishna 2011).

As aforementioned the sensory profiles obtained from analyses may be used in order to entice the consumer and is called sensory marketing (Gustafsson 2014). Describing the product's sensory characteristics may stimulate an emotional response and have been found to play an important role in consumer's food purchase (Wansink et al. 2001; Krishna 2011; Swahn et al. 2012; Turnwald et al. 2019; Jürkenbeck & Spiller 2021).

A flavour focused labelling allows consumers to assess the product in regard to their own preferences which could bring an increased quality awareness to the consumer (Swahn 2011; Gustafsson 2014).

2.5.1. Sensory marketing affects consumer choice

Sensory Marketing was defined by Krishna (2010) as a marketing strategy that engages the consumer's senses and thus affects their behaviour. The major aim is to allow consumers to understand the different tastes of a product type, which in turn might inspire to discover new applications. Research shows that descriptions affect consumer choice and behaviour in various contexts (Gustafsson 2014).

Describing the flavour characteristics of food has been used in restaurants for a long time but using it for marketing is quite new (Språket 2012; Krishna 2010). It has been shown that sensory descriptions improve sales as well as consumer expectations related to foods (Wansink et al. 2001; Swahn et al. 2010; Jürkenbeck & Spiller 2021). By inspiring the consumer, the chance of satisfaction increase (Gustafsson 2014).

A study by Wansink (2005) that was conducted in a restaurant environment, showed that when sensory descriptions were given in the menu, the guests´ choices were affected.

The labels and descriptions within the wine market are considered as helpful by consumers in that they provide important information (Dimara & Skuras 2005).

By obtaining the words to describe the nuances of foods, an added value is created (Swahn 2011; Gustafsson 2014; Jurckenbeck & Spiller). This in turn can be a helpful tool in order to change eating habits, according to researchers at Örebro University (Westling see Renmark 2019; Gustafsson see Larsdotter 2009). Inga Britt Gustafsson, professor in Meal Science at Örebro University argues that expressing the flavour experience with words entail raised awareness and increasing demands on quality of fruits and vegetables (Larsdotter 2009).

2.5.2. The use of sensory marketing for fruits and vegetables

In order to determine the quality of unbranded and unlabelled food products, such as fruits and vegetables, consumers sniff and touch (Sogn-Grundvåg & Østli 2009). Even though the procedure may be of some help to judge a fruit's ripeness, the assessment does not guarantee the eating quality to be satisfying.

Fruits and vegetables are rarely submitted to sensory analysis and the frequency of encountering sensory marketing of fruits and vegetables is low. However, some suggest it to have potential to be a valuable tool to increase consumer acceptance of vegetables (Swahn 2011; Appleton et al. 2019; Turnwald et al. 2019).

In order to reduce the fixation of appearance in fruits and vegetables as well as to optimize consumer perception of these products, researchers at Örebro University argue placing emphasis on the flavour (SVT Nyheter 2009). A few studies have been conducted to obtain a sensory vocabulary describing flavours of vegetables such as peas, onion, baby leaves, apple and potatoes (Larsdotter 2009; Swahn et al 2010; Larsson & Swahn 2011; Gustafsson 2014; Öström & Westling 2015a; Öström & Westling 2015b). However even fewer studies have evaluated the effect of applying sensory words in the marketing of these product in Swedish grocery retail. Swahn and colleagues (2012) showed that consumer product choice was affected by sensory descriptions on apples in Swedish grocery retail. In the case when sort name was given but no other information was presented, consumers chose a familiar cultivar. Whereas, when sensory description was presented, another apple variety was chosen, which was less frequently chosen when the sort names were given (Swahn et al. 2012). The result could also demonstrate that consumer engagement was higher in the case of sensory descriptions (Swahn et al. 2012).

Jürkenbeck & Spiller (2021) studied if existing sensory marketing techniques used in the wine market could be applied in fruits and vegetables. The results showed similar results which Swahn and colleagues (2012) obtained; sensory descriptions of tomatoes and apples were preferred over providing the names of varieties. The authors suggest that the introduction of sensory descriptions for fruits and vegetable is worth considering as the sensory descriptions had an influence on tomato and apple purchases (Jürkenbeck & Spiller 2021). The outcome of the study supports the author's hypothesis that sensory descriptions are important in consumer's product choice of fruits and vegetables and partly supports the hypothesis that sensory quality signals would raise the perceived value of fruits and vegetables, as in the wine market.

In a study by Turnwald (2019), taste-focused labelling on menus increased vegetable selection by 29% compared with health-focused labels and by 14% compared with basic labels. The authors emphasize the potential positive outcomes by replacing healthy descriptions with flavour focused ones (Turnwald & Crum 2019).

2.5.3. Development of the sensory language

Using the same degree of precision describing taste as with vision, without expressing personal sensations such as tasty or delicious, is challenging (Larsson & Swahn 2011).

Most people are able to distinguish between numerous scents, but to translate them into words is harder. A hypothesis on this phenomenon is based on how the brain is organized. The primary odour centre has a direct connection to the anterior temporal lobe, which is the centre for semantic memories – meaning connecting the meaning of words. This is different from visual impressions that travel to the back of the brain and is processed through extensive networks, before it reaches the anterior temporal lobe. In summary, visual impressions creates a greater activity in the brain, which may be the reason why we obtain more words to describe what we see - even if the object is new to us (Jonas Olofsson see Can 2021).

As aforementioned, a large part of the process of sensory analysis intends to identify a vocabulary in order to describe the product's sensory characteristics (Gustafsson 2014). The methods of sensory analysis are useful to obtain the language to use in sensory marketing. But how should the description be phrased to allow those not familiar with the flavour to relate to the description?

Swahn (2011) emphasize that the information in sensory marketing, must be phrased so that consumers can understand and relate to it. The expectations that the descriptions generate, must match the actual experience. If it doesn't, the consumer experience might be negatively affected (Swahn 2011; Gustafsson 2014).

Swahn and colleagues found that consumers had difficulties choosing products if the description were too long and detailed (Swahn 2011).

Choice of words is also of importance (Swahn et al. 2010; Larsson & Swahn 2011; Gustafsson 2014). The description should be objective and identify the sensory properties that make the product unique. Terms such as *fresh* or *tasty* do not commonly engage consumers in the same extent (Gustafsson 2014).

Even though there are numerous studies made to create sensory lexicons for horticultural products, Larsson and Swahn (2011) highlights that little attention has been paid to the linguistic aspects of the sensory language. The attributes mentioned in the descriptions must associate with positive thoughts and feelings to the consumer and using language model based on semantics may enable identifying the words and descriptions perceived as attractive- in order to help consumers to make the right choice. In the work of obtaining a vocabulary of apples were descriptions with the word *perfuminess* found to have a negative effect on consumer choice (Swahn et al. 2010).

Sensory marketing is about educating and inspiring people. Some consumers will make a routine decision either way, while others could be helped by the description and learn what they prefer. Even if people know, or believe to know what they like, expressing it is difficult until they learn how to.

3. Study Methodology

From here and onwards the sensory analysis which forms the experimental part of the present thesis as well as the basis of the project "A culinary road map for Swedish vegetables" is presented. The following sections describe the methodology and discuss concerning the chosen method.

3.1. Experimental Overview

The project *A culinary road map for Swedish vegetables* started in January 2020 by top chef Daniel Berlin and researchers at SLU with the intention to explore the sensory characteristics of some heat-treated commonly used vegetables. Several studies indicate that the genetic material is the most decisive factor for sensory characteristics. This fact justified that the current study aimed to explore the differences between several varieties of vegetables.

During the season of 2020, varieties of carrot (*Daucus carrota*), cabbage (*Brassica oleracea*) and onion (*Allium cepa)* were cultivated in the garden of *Daniel Berlin* restaurant, in Skåne-Tranås, as well as at Bokeslundsgården, Hörby, in Scania, Sweden.

During the spring of 2020 recruitment of the analytical panel was initiated. The project was announced via flyers distributed on the campus of the Swedish University of Agricultural Sciences, Alnarp. In June 2020 a panel of 12 participants was recruited.

In week 37 and 38, 2020, the material of carrot, cabbage and onion were harvested. In parallel, the panel got together for two occasions each week over a three-week period, one for training and the other for evaluation of the harvested products.

The instructions for the method of a descriptive sensory analysis were provided by a consulting sensory expert and carried out as far as possible in accordance with the requirements of the standard method. However, the given circumstances within the project entailed some modifications described briefly in the following sections and further discussed in *Discussion.*

The collected data were submitted to a statistical analysis that was conducted by an experienced sensory expert who was part of the project group. The data from the conducted sensory analyses were then illustrated by spider charts, which is commonly applied within sensory analysis.

3.2. Methods used

The study involves sensory evaluation of three vegetables cultivated all year round in Sweden which are familiar to most Swedish consumers. The fact that carrots carry a familiar flavour, cabbage and other brassicas are popular for their high content of health-promoting compounds and onion is a common flavouring makes them to be often occurring in restaurants as well as in consumer's home cuisine.

The choice to perform sensory analysis of heat-treated products instead of raw was motivated by the fact that this is how they are commonly served at the restaurant *Daniel Berlin*, which in turn is the basis for the quality assessment among the chefs.

The samples were cooked through sous vide technique, which is commonly used in restaurant kitchens. Cooking instructions were given by a chef at restaurant *Daniel Berlin*.

Given that the purpose was to generate attributes that can be used in communication to describe the sensory character of these vegetables, the descriptive sensory method Quantitative Descriptive Analysis (QDA) was chosen. The method was considered suitable since it generates quantitative data which can be statistically analysed and allow examining the degree of agreement within the panel.

QDA generates deep information about a product's sensory characteristics as well as provides identification of differences and similarities between the samples (Lawless & Heymann 2010). The method does not require more than 12 panellists. Due to the presumptive challenges to recruit an adequate number of panellists during the ongoing Covid- 19 pandemic, QDA was preferable compared to other descriptive methods such as for example Repertory Grid Method that demands at least 30 participants (Gustafsson 2014).

Swahn et al. (2010) used a combination of QDA and RGM to generate a comprehensive semantic frame and sensory profiles of apples. While a study conducted by Wrzodak et al. (2012) investigated sensory differences in carrots through the methodology of QDA. Rocha et al. (2013) applied QDA when characterizing cultivars of tomatoes.

The sensory evaluation within the project included assessment of appearance, smell, texture and taste. But due to the aim within this thesis primarily being to explore the variations in flavour between the cultivars, emphasis is placed on taste and aroma analysis.

4. Materials & Method

In the following chapter materials and methods applied in the study are described. Firstly, the collection and creation of the material for the analysis are featured. Additional material is compiled in Appendix. The following subsections cover a description of the procedures within the QDA method- including recruitment of the panel, panel training and analysis.

4.1. Materials

Cultivars

The total, unscreened, material consisted of 8-10 varieties of carrot (*Daucus carrota*), cabbage (*Brassica oleracea*) and onion (*Allium cepa*). Carrot, cabbage and onion were all cultivated at *Bokeslundsgården*, Hörby, Scania while varieties of onion were grown in the garden of *Daniel Berlin* restaurant, Skåne-Tranås, Scania.

The selection of cultivars was based on the aim to get a broad repertoire of samples, in terms of characteristics, shapes and colours. Carrots were harvested in week 37 2020 and analysed later the same week. Cultivars of cabbage and onion were harvested in week 38, 2020, of which cabbage was analysed later the same week. Onion was evaluated the following week and thereby stored for ten days in 4 °C.

Score Sheet

Panel training in QDA commonly involves the procedure of letting the panellists participate in the selection of the score sheet's attributes. The procedure allows the panel to reach a joint agreement on a final score sheet by discussing the collected words (Lawless & Heymann 2010).

However, in this study, the generating of attributes to the score sheet was conducted previous to the training sessions, by the panel leaders in order to save time. As QDA aims to provide a product's complete sensory profile, including many attributes in the score sheet is essential.

The attributes were collected from the literature (Gills et al. 1999; Engel et al. 2002; Talavera-Bianchi et al. 2010; Wrzodak et al. 2012; Öström & Westling 2015b; Johansen et al. 2017; Swegarden et al. 2019). As the samples would be served heat-treated, proper attributes were chosen thereafter. The sensory attributes used in the three separate assessments are shown in ***Table 1.***

The score sheet was categorized into Appearance, Smell, Texture, Flavour and Aftertaste and each attribute was paired with a 10 cm continuous structured intensity scale ranging from 0 to 100, as shown in *Appendix 5*.

Table 1 *Swedish and English sensory attributes used in the assessments.*

Carrot		**Cabbage**		**Onion**	
Sv	Eng	Sv	Eng	Sv	Eng
Doft - Aroma					
Morotsdoft	Carrot	Kåldoft	Cabbage	Lökdoft	Onion
Sötma	Sweetness	Sötma	Sweetness	Syrlighet	Sourness
Jordighet	Earthiness	Örtighet	Herbaceous	Friskhet	Freshness
Nötighet	Nuttiness	Pepprighet	Pungency	Örtighet	Herbaceous
Örtighet	Herbaceous	Svavel	Sulfurous	Stickande lukt	Pungency
				Svavel	Sulfurous
Smak - Flavour					
Smakintensitet	Overall intensity	Smakintensitet	Overall Intensity	Smakintensitet	Overall Intensity
Sötma	Sweetness	Sötma	Sweetness	Sötma	Sweetness
Beska	Bitterness	Beska	Bitterness	Beska	Bitterness
Syrlighet	Sourness	Syrlighet	Sourness	Syrlighet	Sourness
Nötighet	Nuttiness	Nötighet	Nuttiness	Sälta	Saltiness
Sliskig sötma	Sickly sweet	Gräsighet	Green grass	Örtighet	Herbaceous
Jordighet	Earthy	Pepprighet	Pungency	Metallisk	Metallic
Gräsighet	Green Grass	Metallisk	Metallic	Fruktighet	Fruitiness
Blommighet	Floral	Friskhet	Freshness	Friskhet	Freshness
Fruktighet	Fruitiness	Svavel	Sulfurous	Svavel	Sulfurous
Parfymighet	Perfuminess	Eftersmak	After taste	Hetta	Heat
Kemisk smak	Chemical			Eftersmak	After taste
Pepprighet	Harshness				
Eftersmak	Aftertaste				

Venue

Sensory evaluations are preferably conducted in sensory laboratories free from odours and equipped with white natural light as well as bright walls and surfaces (Gustafsson 2014). Panellists should preferably be placed in separate cubicles, to eliminate the risk of facial expressions and eye contact having an impact on other panellist's assessments (Gustafsson 2014). Due to *The Swedish University of Agricultural Sciences* not being equipped with a sensory laboratory, the analyses within this project were conducted in venues considered as suitable as possible for the purpose.

Two sessions were held in a conference room and the third evaluation session was held in two small separate rooms, which resulted in splitting the panel into two groups. The analyses were conducted without individual cubicles. Instead, the panel was placed around a large table and given the instructions to avoid eye contact and to not look at other panellists.

4.2. Method - Quantitative Descriptive Analysis

4.2.1. Panel Recruitment

Recruitment of the sensory panel was initiated through the distribution of a n advertising flyer, see *Appendix 2*. To reach people with the ability to attend to the location of analysis, the flyer was distributed at the campus of *The Swedish University of Agricultural Sciences*.

A digital questionnaire, see *Appendix 1*, was sent to the 23 applicants who had answered the ad. The candidates being available for panel work during daytime and not having food allergies or taking medicine were screened further. The prospective panellists then performed a blind basic taste test and odour test. The basic taste test involved the identification of aqueous solutions of sucrose, sodium chloride, citric acid and caffeine at various concentrations while the odour test involved the identification of five anonymous fragrances: cinnamon, honey, melon, celeriac and ginger. See *Appendix 3* for preparations as well as instructions of performance.

Due to the low number of people applying to be part of the panel, additional tests to restrict the number of participants was not needed.

Twelve applicants - seven men and five women within the ages of 20-61 qualified to be part of the panel. 25% of the participants were students, 58% staff members and 17% employed outside of the university.

4.2.2. Sample preparation

The preparation of samples was conducted in a laboratory kitchen at the campus on the day before the panel sessions. Depending on training or analysis, the material constituted of three or six cultivars respectively. In analysis, each cultivar was analysed in replicates.

Carrot
Carrots were washed and peeled using a potato peeler. 1 cm from the crown and the tip of each carrot were discarded. The remaining piece was cut into 5 cm lengths, enough for the panellists to have three bites. Pieces were cut in order to be as similar looking as possible.

Cabbage
To make the samples as homogenously looking and tasting as possible, the cabbages were prepared by removing the inner and outer layers, leaving ca six of the middle layers for evaluation that were subsequently cut in triangles.

Onion
Because the material of onion varied in size, the samples were cut into approximately the same size of 4 cm pieces after being peeled.

Carrot, Cabbage and Onion
The cut samples were placed spaciously in sous vide plastic bags labelled with cultivar name, and thereafter placed in a vacuum machine (*Food Saver V2860*) and

sealed. Some of the bags were intended for trying optimal cooking time in the oven. The remaining bags were stored in 4 °C overnight.

On the day of a panel session, the bags were collected from the fridge and put at room temperature for one hour. One hour before the panel session, the bags were put in a *RATIONAL* Oven. Cooking times and oven settings are shown in ***Table 2***. The samples were taken from the oven and placed on paper plates.

Table 2 *Oven settings for the heat treatment of samples.*

Type of sample	Oven setting/Temp (°C)	Time (min)
Carrot	100 % steam / 85	25
Cabbage	100 % steam / 85	30
Onion	100 % steam / 85	35

4.2.3. Panel Training

Within QDA, the process of panel training commonly requires hours of work and involves the steps of generation of attributes, definition of attributes and calibration of panellists (Gustafsson 2014). These procedures aim to allow the panel to develop a common language and use intensity scales. During training, test samples are served, and the panel leader works as a communication facilitator without involvement in panel discussions.

In this study, the panel was trained for 2 hours for each vegetable, one or two days previous to analysis. The sessions included 45 minutes of a test evaluation and one hour of panel discussion.

During the test evaluation, the panel was served three samples, marked A, B or C and instructed to analyse the samples in the order from A to C. After evaluation, a discussion, facilitated by a panel leader, was held to allow the group to work with the given list of attributes and determine which to remove, keep and add, see ***Table 1.***

4.2.4. Sensory Analysis

Each evaluation occasion was split into two sessions with a ten-minute break in between. Six samples were served per session, in total 12 samples.
The panel evaluated the samples in a balanced sequential monadic order (one at a time).

A randomized serving order was made for each panellist. Whenever a panellist was finished with a sample, they raised their hands to be served the next sample. Each panellist was equipped with a sample, protocol, pencil, a glass of water, a spit jar and some neutral crackers to cleanse the palate between the samples. They were instructed to avoid swallowing but spit in between samples and rinse with water.

4.2.5. Statistical Analysis

The data from the analysis were processed by registering the scores in an Excel spreadsheet, and analysed through a 2-way Analysis of Variance (ANOVA) model with main effects of sample and assessor and its interaction, using software Panel check v 1.4.2.

Mean values of the intensity ratings of each attribute were calculated and illustrated in a spider chart. The spider charts illustrate the results of a one-way ANOVA with cultivar as source of variation.

5. Results

In this chapter the results from the conducted sensory analysis are presented. The charts in Figures 1-6 show mean values of the scored taste and aroma attributes from the sensory evaluations. Each vegetable is coded with abbreviations; Ca for carrot, Cb for cabbage and On for onion and numbers refer to one of six cultivars.

Carrot

The output of the ANOVA showed a significant product effect in 13 out of the total 23 attributes, see *Appendix 6*. In flavour, significant variations appear in overall flavour, sweetness, nuttiness and fruitiness, perfuminess and aftertaste and non-significant variations in sourness, green grass and floral flavour, see ***Fig. 1***.

Ca1, Ca2, Ca3 and Ca4 obtained similar mean intensities in many flavour attributes, except that Ca4 differed from the others with a higher mean score in

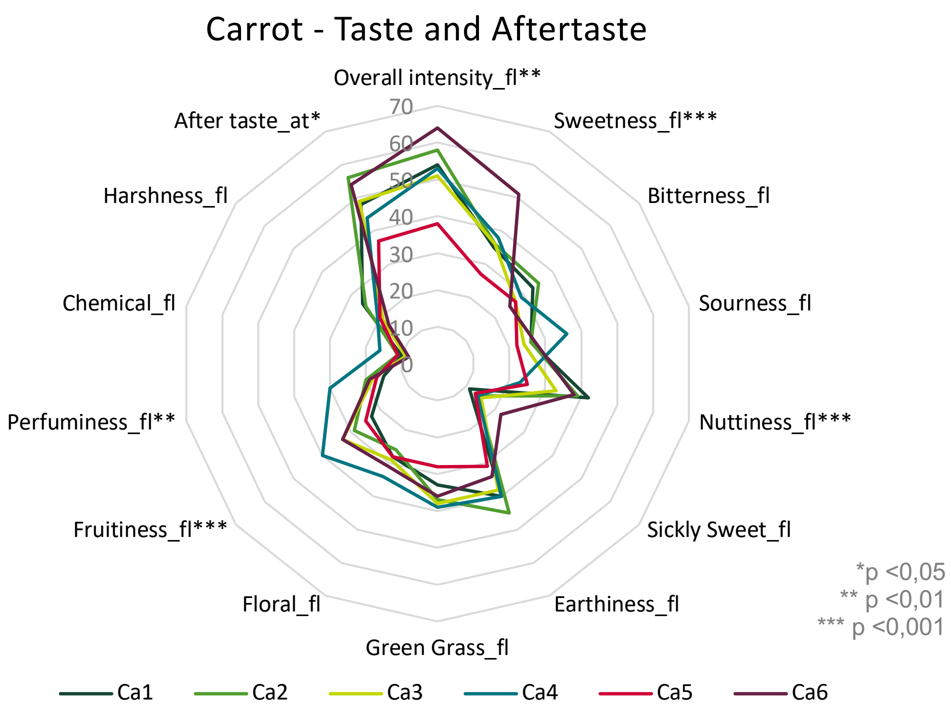

Figure 1. *The taste and aftertaste profile of the six cultivars of carrot. The chart shows mean intensities on a scale from 0 to 100. There is a significant difference between the samples in the attributes overall flavour, sweetness, nuttiness, fruitiness, perfuminess and aftertaste.*

sourness, fruitiness and perfuminess and low scores in nuttiness and Ca2 shows the highest values of all cultivars in aftertaste.

Ca1 and Ca2 showed almost identical sensory profiles in flavour profiles and was characterized with the highest scores in nutty and earthy flavour, being significantly different from Ca5 and Ca4.

Sweetness is one of the most appreciated features of carrots (Kjellenberg 2007). The results obtained in this study indicate sweet taste to be significantly different between some of the cultivars. Ca6 distinguished from the other four by obtaining the highest average scores in sweetness, overall flavour intensity and aftertaste. Ca5 scored low in these attributes and in many of the other attributes as well.

Small variations appear in bitterness, sickly sweet, harshness and chemical flavour.

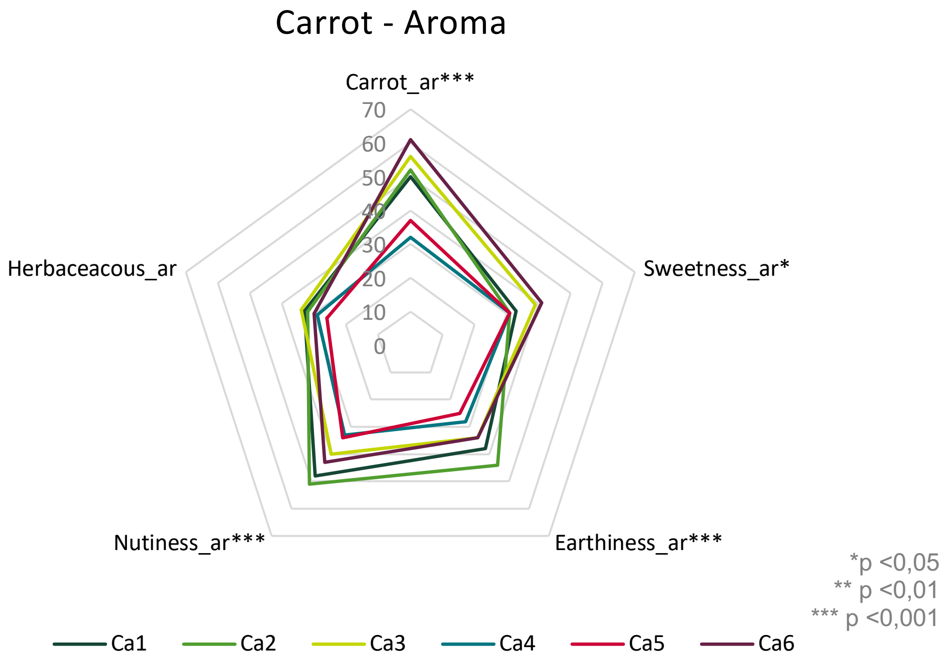

Figure 2. *The aroma profiles of six carrot cultivars. Significant variations appear within sweet, nutty and earthy as well as carrot aroma. Ca4 and Ca5 is indicated to be the least aroma intense cultivars. Ca6 and Ca3 scored highest in carrot aroma. The chart demonstrate that Ca1 and Ca2 had the most nutty and earthy aromas, as in the taste chart.*

Regarding aromas, significant differences appear within carrot, earthiness and nuttiness, see ***Fig. 2***. Ca6 distinguished from the other with high carrot aroma intensity and a distinctly sweet aroma. Ca3 follow Ca6 relatively well, but with a lower mean intensity.

Ca1 and Ca2 obtained moderate scores and similar aroma profiles, with high averages in earthy and nutty notes, as in flavour. Ca4 and Ca5 obtained low mean intensities.

Cabbage

Based on ANOVA, significant differences between the cultivars were found in 10 out of all 26 attributes, see *Appendix 6*.

Results show that all six cultivars obtained quite similar sensory profiles, however prominent and significant variations in intensities appear within the attributes overall flavour, bitterness, fruitiness and freshness and non-significant variations are shown in aftertaste, nuttiness and sourness, see ***Fig. 3***.

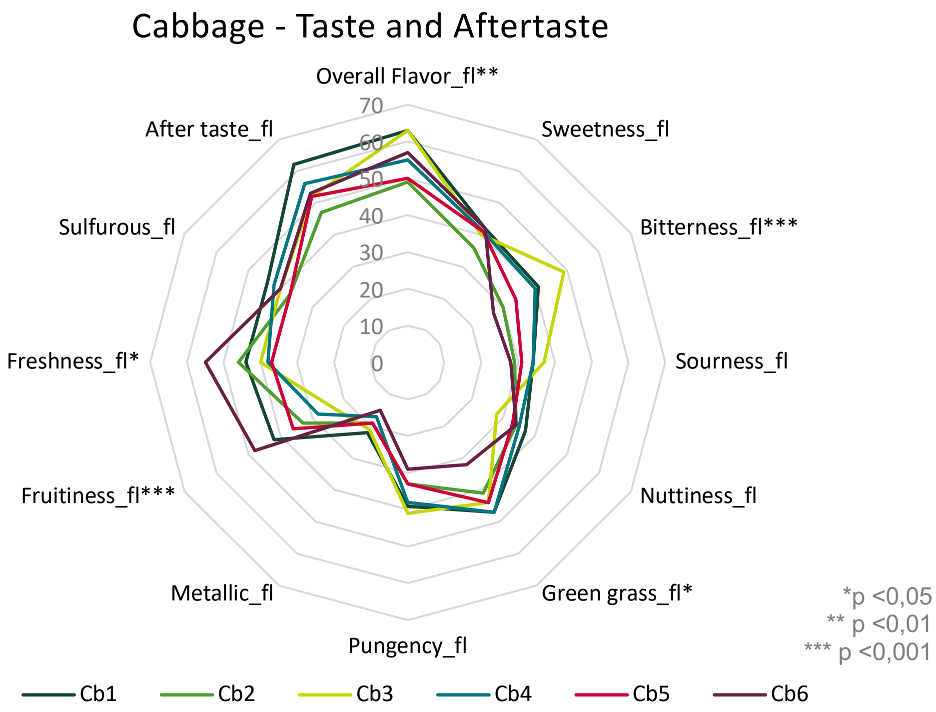

Figure 3. *The six different taste and aftertaste profiles of cabbage cultivars. The chart shows significant differences between the samples in the attributes overall flavour, bitterness, green grass, fruitiness and freshness. All profile follow each other relatively well except for the attributes bitterness, green grass, pungency, fruitiness and freshness, where Cb3 show highest bitterness and Cb6 the highest freshness and fruitiness.*

Cb6 differed from the others with a prominent fruitiness and freshness and distinctively low intensity of green grass.

Attributes related to typical characteristics of Brassicas (broccoli, kale, brussel sprouts and cabbage) are bitterness, pungency and notes of sulfur, caused by the presence of glucosinolates and sulfurous compounds (Talavera-Bianchi et al. 2010).

Intensities of sulfur and pungent flavour reached low to moderate levels and did not differ noteworthy between the cultivars. Cb6 was the least pungent in flavour and aroma and also considered the least bitter. Cb3 show a prominent high value in bitterness and obtained together with Cb1 the highest mean intensities in overall flavour intensity.

The average ratings of sweetness and metallic flavour did not differ between the cultivars.

The results of ANOVA show no significant product effect among any of the aroma attributes, see ***Fig.*** *4*. The spider chart indicates the aroma attributes to be present in low to moderate intensities in all cultivars, with mean values not differing noteworthy.

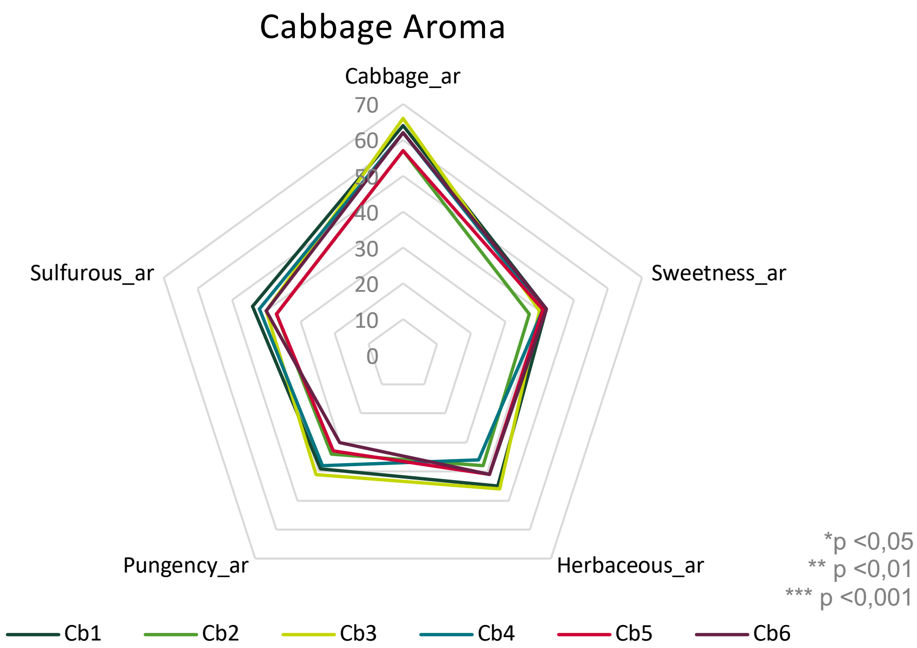

Figure 4. *The aroma profiles of the six cabbage cultivars. The chart indicates there to be little variations between cultivars in concerns to aroma attributes.*

Onion

The output of ANOVA showed 15 attributes out of the total 24 to be significantly different between the cultivars of onion, see *Appendix 6*. In flavour attributes, significant variations appear within overall flavour, sweetness, bitterness, freshness, pungency and sulfurous flavour and aftertaste, see ***Fig. 5***. Non-significant variations can be seen in metallic and fruitiness while sourness, saltiness and herbaceous notes scored low in all cultivars.

Sweetness and pungent flavour and sulfurous aroma are typical sensory characteristics of onion (Crowther et al. 2005).

On6, which is a cultivar commonly found in retail, had few pronounced characteristics and differed from the other cultivars with a low average in overall flavour intensity, pungency, bitterness and sulfur flavour.

On3 and On5 distinguished from the other with the highest mean scores in overall flavour, pungency and aftertaste. Their profiles follow each other relatively well except in the attributes freshness and fruitiness where On3 had the highest values.

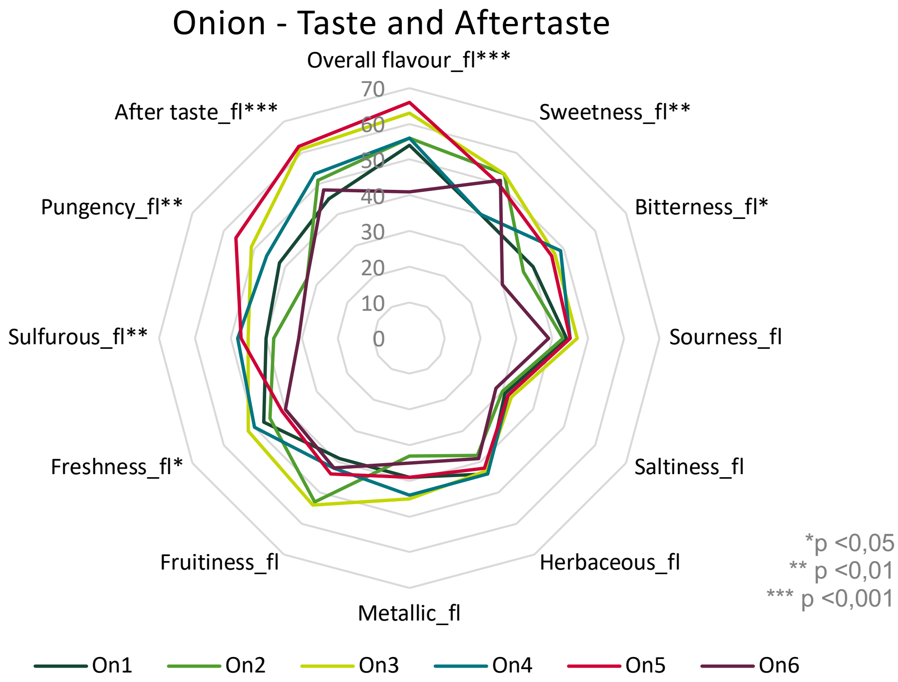

Figure 5. *The taste and aftertaste profiles of all six onion cultivars. The output of ANOVA shows significanct variations within overall flavour, sweetness, bitterness, freshness, sulfurous, oungency and aftertaste. On3 and On5 shows highest intensity in overall flavour, pungency and after taste. On6, which is occurring in retail, obtained low values through all attributes except for sweetness and after taste..*

Sulfurous flavour was scored at low to moderate intensities, however On3, On4 and On5 seem to have been considered as having the highest intensity.

Sweetness is indicated to have been present in higher levels in four of the cultivars but much lower in On1 and On4.

Within aroma attributes, significant variations appear in freshness, pungency and sulfurous aroma, see ***Fig. 6***. The charts demonstrate that aroma attributes scored not higher than 50, but variations between the cultivars appear.

On6 scored lowest through all aroma attributes, whereas On3, On4 and On5 obtained the highest average scores. On4 differed with lower intensity in pungent and sulfur aroma and On5 differed oppositely, with lower intensities in sourness and freshness.

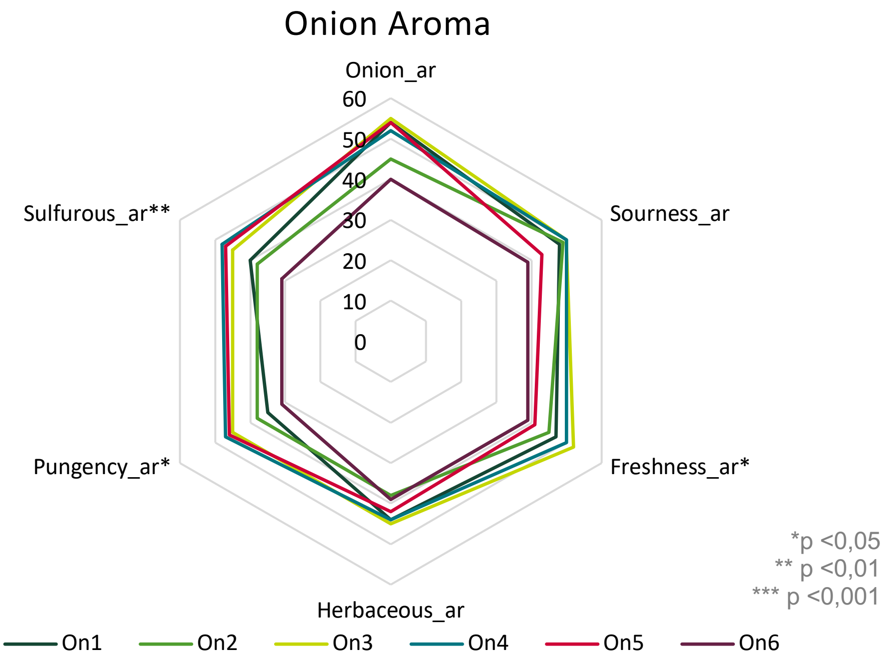

Figure 6. *The aroma profiles of the six cultivars of onion. There are variations within all attributes, however significant variations appear within freshness, pungency and sulfurous aroma. On6 scored lowest through all aroma attributes, whereas On3, On4 and On5 obtained the highest average scores.*

6. Discussion

In this section the results and method are discussed with regards to the literary study as well as research questions.

Normally, when addressing issues facing agriculture, the aspect flavour is not often mentioned. However, in the current literary review, a number of benefits of describing flavour were explored. Much point to that positive effects might be attained by highlighting flavour quality in marketing and communication of fruits and vegetables (Larsdotter 2009; Krishna 2011; Swahn 2011; Gustafsson 2014; Renmark 2019; Turnwald et al. 2019; Jürkenbeck & Spiller 2021). Some argue that the flavour aspect is worth considering as a mean to improve vegetable consumption and quality awareness among consumers (Kader 2008; Gustafsson see Larsdotter 2009; Klee 2010; Swahn et al. 2012; Barber 2014; Healy 2017; Westling see Renmark 2019; Hoppu et al. 2020). Realistically, horticultural products are commonly produced under limited recourses, implying that applying sensory analysis is not likely to be prioritized. The fact that flavour of fruits and vegetables is perishable and difficult to control, assess and guarantee (due to numerous factors within cultivation and post-harvest having an impact) makes standardization of sensory quality challenging (Mattheis & Fellman 1999; Forney 2013). On the other hand, as cultivation techniques are improving, especially in greenhouse production where the environment is easier to control, future cultivation techniques might allow better circumstances for standardization of flavour quality in fruits and vegetables (Gruda 2005).

The current penchant for horticultural products with flawless appearance is partly explained by both rational and practical aspects within the regulated standardizations. Some literature indicate that the tendency may also simply be explained by the fact that sight is considered to be the dominating sense and has been so for a long time.

Research address that sensory characteristics is an important aspect in the consumption of fruits and vegetables (Pollard et al. 2002; Barrett et al. 2010; Cox et al. 2012; Appleton et al. 2019; Turnwald et al. 2019). Much point to the fact that consumers as well as chefs care for other qualities and that products with satisfactory eating quality could be an important means of competition.

A potential scenario of having more of a flavour focused approach through using a sensory vocabulary provides circumstances for consumers to appreciate and assess other aspects of quality than shelf life and appearance in fruits and vegetables. Highlighting taste and aroma may thereby benefit both consumers and retail.

The present exploratory study was initiated based on a chef's experiences of a limited supply of horticultural products that meet the requirements he and other chefs have concerning exceptional flavour quality. Part of the problem statement also involved the challenges in communicating this aspect of quality to colleagues and others within the supply chain, in order to find the quality that is searched for.

Three vegetables commonly used in the Swedish cuisine were submitted to sensory analysis to explore their sensory attributes and to examine if a panel with limited training could achieve consensus concerning their sensory characteristics. By achieving consensus, the sensory attributes could be used as guidance in sensory descriptions of the three vegetables.

The current study used the descriptive method of QDA and against the background of the first research question, the results demonstrate that the method was suitable for the generation of attributes.

Within QDA, the differences between samples found is a relative measurement while the absolute value is neglected (Lawless & Heymann 2010). Given that a well-trained panel is hired, the information on intensity and relative proportions from the evaluation could yield a detailed sensory image. The attributes and their relative measurements within our study should however be viewed as indicative as our panel performed limited training.

The results demonstrate that mean intensities of attributes vary between the cultivars of carrot, cabbage and onion and the statistical analysis show significant variations in around half of the attributes. This could be seen as an indication that there are distinguishable differences in characteristics between the cultivars.

Within each vegetable, cultivars showed significant variations within overall flavour intensity. Between the carrot cultivars significant variations appeared within sweetness, nuttiness, perfuminess, fruitiness and aftertaste and in cabbage cultivars significant variations were found in bitterness, freshness, fruitiness. Significant variations between the onion cultivars appeared in the attributes sweetness, bitterness, freshness, pungency, sulfurous and aftertaste.

The significant variations indicate a partly agreed panel concerning the sensory differences, which in turn can be considered as a sign of a consensus within the panel regarding these attributes.

The non-significant variations within some attributes may be explained by inabilities within the panel, for example inconsistent use of intensity scales from person to person. Alternatively, there could have been variations in the material depending on the part of the sample. In carrots, the sweet and bitter taste develop differently in different parts. The sweet flavour is often more pronounced in the centre and lower tip. While bitterness is more often prominent in the upper part (Kjellenberg 2007). If this is the case, it may cause inconsistent ratings between replicates.

The results also demonstrate attributes appearing in little variation or low intensities through all cultivars. This may be a sign of them being more difficult than other attributes to evaluate by a panel with limited training.

This study used heat-treated products as it is how chefs often evaluate the product's suitability to their menu. Performing analysis on heat-treated material might be another factor that makes it challenging for a panel with limited training to detect attributes, as some characteristics can be perceived as less prominent when cooked. Bitterness in cabbage and carrot is more prominent in their raw state than in cooked (Wrzodak et al. 2012). In onions, sugars form a major part of soluble solids but may be difficult to perceive in raw state due to the overriding effect of the sulfur-based flavour compounds. Cooking entails the strong sulfur volatiles to vaporize and pungency is expected in lower intensities, which in turn allows the sweetness to become more pronounced (Crowther et al. 2005).

The few significant variations within the attributes of cabbage aroma may indicate that they were more difficult to assess. Evaluating a high number of samples with intense smell, as heat treated cabbage can hold, there is a risk that the sense of smell of the panellists adapt within a short time, entailing a reduced sensitivity (Gustafsson 2014).

When taking part in previous studies performing QDA on fruits and vegetables, the literature mainly involves raw material. The fact that the material in this study was heat treated entails that the results are difficult to compare with previous studies', since it implies another selection of attributes.

The procedure of panel training makes QDA time demanding. Alternative descriptive methods that can generate a corresponding broad register of terms may have required equal number of hours, but more participants and competence from the panel leader. Repertory Grid Method (RGM) is a descriptive method that is advantageous since no training of a panel is needed. However, the procedure of RGM requires a higher number of participants to conduct one hour each of individual analyses per product (Gustafsson 2014).

Considering the presumptive and actual difficulties in recruiting due to the ongoing Covid-19 pandemic, QDA was advantageous in the sense that the methodology recommends 10-12 panellists. Even though 12 panellists were recruited there were 7-9 persons performing analysis, due to the pandemic restrictions not allowing participants with symptoms of illness to be among other people. A fewer number of panellists implies a reduced reliability for the results.

In normal conditions, the recruitment flyer could have reached a higher number of people, allowing a higher number of participants with a higher representation to apply.

During training, the panel should have enough time to get familiar with the varieties of the product, its sensory characteristics as well as the intensity scales. In literature, studies performing descriptive analysis provide between ten to hundreds of hours of training, where the one with less than 10 hours of training engaged participants especially trained for descriptive analysis (Gills et al. 1999; Engel et al. 2002; Talavera-Bianchi et al. 2010; Wrzodak et al. 2012; Rocha et al. 2013a; Johansen et al. 2016; Swegarden et al. 2019). This study was of exploratory manner and the results cannot compare to studies applying sensory analysis with extensive hours of panel training.

Potential limitations within the current study were that modifications were done in order to work in line with the limited economical and practical resources. For example, the budget did not allow the time needed to reach adequate panel calibration or to provide supplements such as reference samples or a list of definitions of the attributes that could have simplified the training procedure.

It was not possible to offer the panellists payment and so, panel work competed with their other occupations. Consequently, the participants could not be asked to train as much as would have allowed them to get even more acquainted with the score sheets and attributes, which is a prerequisite to achieve a completely calibrated panel.

Another modification in this study involved providing the panel with attributes during training, in contrast to the ordinary methodology giving the opportunity to the panel to collect the attributes together through discussions. This fact entailed that the panel was not allowed to identify attributes, which in theory would have resulted in other attributes than those compiled from the literature. Through collecting attributes from literature, the cultivars within this study were thereby referenced to attributes that were used in studies with circumstances and cultivars different from this.

In addition, the relatively short panel training session did not allow sufficient time for discussion of attributes. The limited time provided could entail a potential risk that individuals with stronger opinions may have influenced other participants' ways of expressing themselves in the discussion, which can have had an impact on consensus in the selection of attributes.

This study has been a clear example that sensory analysis is time-consuming and that it is difficult to make modifications while maintaining reliability.

The factors mentioned above make it difficult to ensure that the sensory profiles illustrate the actual proportion and intensities of the attributes analysed and the sensory profiles obtained should therefore be read with caution.

This study has identified the sensory attributes and differences that may be used to describe the characteristics of various vegetables. Thus the generated vocabulary may be considered as a contribution to increased knowledge on the quality aspect of flavour.

A vocabulary for flavour allows distinguishing between typical, atypical and extraordinary flavour variations within a product type. As flavour is an important variable for chefs and for consumers, it is motivated to consider using sensory descriptions of fruits and vegetables. Identifying variations within products could facilitate communication between consumers, chefs, retail, suppliers and producers concerning flavour quality. An increased use of a sensory language to describe flavour variations may contribute to enabling a consensus and united conception concerning flavour quality within the supply chain of fruits and vegetables (Hedberg see Meny 2018).

Initiatives such as *Exceptionell Råvara*, *Tala Smak* in Sweden and the global network of chef Dan Barber can be seen as examples of a strive among people working within gastronomy and dining to find platforms to facilitate the communication of flavour and work towards a higher quality than what is required by the common quality standards.

By communicating flavour, consumers are allowed to reflect upon the variations of flavour of fruits and vegetables which in turn allow them to make a decision based on their own preferences. Also, flavour descriptions may also show the already existing potential and gastronomic diversity in Swedish horticultural products (Swahn 2011; Gustafsson 2014; Westling et al. 2019). This is valuable in the sense that the chances for customer satisfaction as well as quality awareness may increase, which in turn could have an impact on the demand for fruits and vegetables. (Gustafsson 2014; Swahn et al 2012).

Hence, applying a flavour driven approach in the communication of horticultural products can be a tool to obtain increased consumer demands and should therefore be considered.

Suggestions for future work

One major question raised during the conducted study has concerned the challenge in performing sensory analysis in a simple but reliable manner. In order to improve circumstances for obtaining sensory descriptions within horticulture, it is justified to further investigate alternatives to conduct a modifiable but at the same time reliable method for sensory analysis that may result in descriptions.

After learning about the networks in the U.S. involving chefs in the breeding process as a mean to save time (Beans 2017), using chefs as a tool in analyses to obtain sensory descriptions should be considered.

Also, similar initiatives such as *Culinary Breeding Network* that involves chefs, producers and breeders could potentially favour the restaurants and producers in Sweden, as the collaborations support restaurants and growers through identifying cultivars meeting the demands of both actors.

Another question raised at an early stage of the present study is to what extent growers in various scales choose seeds based on other aspects than yield and resistance, for example flavour quality. Is this aspect considered among growers at all, which growers do, and could this way of working benefit this group in some way?

In order to gain more insight concerning the flavour of Swedish horticultural crops, studies concerning the effect of cultivation site on flavour should also be highlighted. The project *A culinary roadmap to Swedish vegetables* was from start intended to involve this aspect but was not possible carry out though.

The project was also intended to connect flavour attributes to “indicators” (such as secondary metabolites) in the produces. However, the limited resources that was provided within this pilot project did not allow to include these objectives. Approaching these questions in Swedish circumstances could be of interest to contribute to further understanding of the factors contributing to flavour.

One conclusion made during the course of the study is that there are few studies in Sweden that have looked into potential effects, other than consumer choices, of sensory marketing in fruits and vegetables. Means and motivation to use sensory descriptions within the supply chain as well as in retail towards consumers is currently missing. Studying its impact on sales and consumer satisfaction may bring valuable insights and knowledge to the area.

Also, studying consumer liking of Swedish horticultural products and flavour should also be considered. The more data that is collected on liking and sensory characteristics, the better are the circumstances to impact what is produced and how to produce it. Improving this kind of knowledge could possibly also contribute to evaluating ways to increase the demand on Swedish grown fruits and vegetables.

7. Conclusions

Through using a descriptive sensory analysis, this study explored the sensory attributes to describe the characteristics of heat-treated cultivars of carrot, cabbage and onion. The study also evaluated whether a consensus within a sensory panel with limited training could be obtained.

One outcome of the study is that significant variations within a part of the attributes were found, which thereby could indicate a partly achieved consensus within the panel. Significant variations were found in sweetness, nuttiness, perfuminess and fruitiness in cultivars of carrot and in bitterness, freshness, fruitiness in the cultivars of cabbage. Between onion cultivars variations were significant within the attributes sweetness, bitterness, freshness, pungency, sulfurous flavour and aftertaste.

In the literary study, aspects of the advantages of using sensory descriptions in the communication towards consumers were identified. Sensory marketing has previously been found to influence consumer behaviour and allows the consumer to make a purchase decision based on their own preferences. By providing sensory descriptions, consumers learn about diversity in flavour which may potentially increase the chance of quality awareness as well as consumer satisfaction. These factors could contribute to increased consumer demand for horticultural products.

The generated attributes in this study can be considered as a contribution to increased knowledge on the quality aspect of flavour, as a vocabulary make it possible to distinguish between typical, atypical and extraordinary flavour. The perceptions by the panel on the sensory attributes may be seen as guidance to sensory descriptions, as consensus was attained. The use of sensory descriptions might facilitate communication concerning flavour quality between members of the supply chain as well as consumers.

One limitation of this study was that even if the panellists had gone through training, more training hours would be desirable, with regard to improving the panels' ability to detect attributes and reproducing assessments. This illustrates the challenge in modifying sensory analysis methods and still obtain reliable results. Inadequate panel training implies that the characteristics presented herein should be considered as indicative. To validate the results obtained in this study, further sensory analysis is needed, with an extended panel training. In order to improve the circumstances of applying sensory descriptions within horticulture, it is suggested to further explore means to achieve a time efficient and also reliable method for developing a sensory vocabulary.

This thesis hopefully contributes to broaden the view on quality of fresh fruits and vegetables as well as provide a deeper understanding of the importance and potential advantages of addressing and describing flavour of fruits and vegetables.

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Appendix 1 – Recruitment questionnaire

Jag godkänner att SLU lagrar de personuppgifter och svar som jag lämnat för att kunna kontakta mig om jag blir antagen till rekryteringsträff. I det fall jag inte blir antagen kommer SLU att radera mina svar och personuppgifter. Ja Nej
Talar du flyttande svenska? Ja Nej
Jobbar du inom områden som restaurang, media eller reklam? Ja Nej Utveckla____________________
Vad är din nuvarande huvudsakliga sysselsättning? Arbete Studerande SLU anställd Annat Utveckla____________________
Hur gammal är Du? 18-31 år 32-45 år 46-50 år 51-65 år 66-75 år 75-80 år
Är du allergisk eller överkänslig mot något/några allergener? Ja Nej Utveckla____________________

Finns det någon typ av livsmedel som du inte tål eller av annan orsak inte kan eller vill äta?

Ja
Nej Utveckla____________________

Har du erfarenhet av någon sorts provsmakning?
(t ex vinprovning, tidigare analytisk grupp eller sensoriska tester)

Ja
Nej Utveckla_____________________

Lider du av någon av följande sjukdomar?

- Diabetes
- Kroniska tandbesvär
- Kroniska besvär från svalg och munhåla
- Kronisk bihåleinflammation

Ja
Nej Utveckla_____________________

Tar du någon medicin som du vet påverkar dina sinnen, framförallt doft och smak?
Ja
Nej Utveckla_____________________

Snusar eller röker du?
Ja
Nej

Smakpanelen kommer att träffas ett par gånger i veckan dagtid på Alnarp, ca 2 h per träff.
Har du möjlighet att närvara dagtid i den utsträckningen under ca 2 månader hösten 2020 och 2021? (augusti och september)

Vilka dagar i veckan och vilka ungefärliga tider är att föredra enligt dig för att du ska kunna närvara på smakapanelens träffar?

Ringa in de grönsaker som du inte äter:
Lök
Morötter
Kål
Tomat
Broccoli
Annat_______________

Annat som du önskar tillägga till svarsformuläret eller som kan vara bra för oss att veta?

Fyll i nedanstående kontaktinformation innan du avslutar

Namn: ______________________________

Personnummer (ÅÅMMDD) _________________________
Telefonnummer (mobil) _________________________
E-postadress: _________________________

Tack för att du har tagit dig tid att besvara frågorna!
Om du passar in i målgruppen återkommer vi till dig via mail med mer information kring testet.

Appendix 2 - Advertising of recruitment of Sensory Panel.

Figure A – Advertising flyer for panel recruitment

Appendix 3 – Recipes for the Basic taste test

Genomförande
- Av varje kemikalie görs en stamlösning som spädes till 3 olika koncentrationer
- Ett prov av vatten
- Proven ska vara rumstempererade vid servering
- Servera 25 ml av varje prov till varje bedömare
- Servera först den starkaste koncentrationen av varje smak, märkta sött, salt, surt, beskt, vatten som referensprov. Detta för att bedömarna ska veta vilka smaknyanser de letar efter
- Varje lösning samt vatten ska kodmärkas och dokumenteras med tresiffriga koder (13 koder)

Stamlösningar

SÖTT: 10% suckros	100g suckros/900g vatten
SALT: 1% NaCl	10g NaCl/990g vatten
SURT: 0,5% citronsyra	5g citronsyra/995g vatten
BESKT: 0,1% koffein	1g koffein/999g vatten

SÖTT		**SALT**		**SURT**		**BESKT**	
10% suckros:		1% NaCl		0,5% citronsyra		0,1% koffein	
spädes:		spädes:		spädes:		spädes:	
1	20g/980g	4	10g/990g	7	20g/980g	10	60g/940g
2	40g/960g	5	30g/970g	8	40g/960g	11	140g/860g
3	***60g/940g***	***6***	***60g/940g***	***9***	***60g/940g***	***12***	***270g/730g***

Kursivt= Den starkaste koncentrationen är den s.k. kända lösningarna som även märks med sött, salt, surt och beskt
Rent vattenprov nr 13 tillkommer. I tabellen så finns det nr 1-13

Varje bedömare ska ha fyra referensprover (de starkaste lösningarna), vatten, rån och 13 kodade lösningar.

Appendix 4 – Basic taste test, Instruction to the participants

Instruktioner Grundsmakstest

Syfte
Med grundsmakstest testas bedömarens förmåga att identifiera grundsmakerna sött, surt, salt och beskt i olika koncentrationer.

Välkomna hit!
Idag kommer ni att få testa olika grundsmaker och dofter som ni ska försöka identifiera. Vänta med att smaka tills ni fått all information.
I båsen har ni en bricka med 13 + 4 muggar. Längst fram finns 4 referensmuggar med grundsmakerna sött, surt, salt och beskt. Ni börjar med att smaka på dessa för att bekanta er med dem.
De 13 övriga muggarna innehåller lösningar av grundsmakerna i olika styrkor (3 av varje). Det finns även en mugg som bara innehåller vanligt vatten. Ni ska smaka på alla dessa och identifiera vilken grundsmak som finns i vilken mugg. Var noga med att skölj munnen med vatten efter varje prov.
På bordet i mitten står 5 stycken doftkärl – ni ska identifiera dofterna i dessa. Vicka inte för mycket på kärlen då det finns lufthål på ovansidan.
I båsen har ni 2 lappar. På den ena fyller ni i vilken grundsmak ni tror finns i respektive mugg – var noga med att skriva ert svar vid rätt kod. Kommentarer är frivilligt.
På det andra bladet fyller ni i vilka dofter ni känner i de olika doftkärlen.
Var noga med att skriv namn på båda lapparna innan ni går.
Ni har ca 45 minuter på er här inne och när ni är klara får ytterligare information och kommer kunna ställa frågor.
Glöm inte att sätt mobilerna på ljudlöst och vi ber att inte prata under testets gång. Har ni frågor så tar vi dem viskande. Det viktigt att vi är så tysta som möjligt så att alla kan koncentrera sig.
Lycka till!

Appendix 5 – Score Sheet

Protokoll morötter i projekt Smakjakt

Namn ________________

Kod (provet) ________

- Titta på provet och bedöm utseende.
- Lukta snabbt och bedöm doft.
- Bit av en (inte för liten) bit och tugga. Bedöm smak / textur. Tugga till provet känns klart att svälja.
- Spotta ut.
- Bedöm eftersmak någon minut efter att du spottade ut provet och skölj med vatten.

För samtliga skalor gäller:

Ingen Mycket

Utseende

Färgintensitet

0 10 20 30 40 50 60 70 80 90 100

Doft

Morotsintensitet

0 10 20 30 40 50 60 70 80 90 100

Söt

0 10 20 30 40 50 60 70 80 90 100

Jordig

0 10 20 30 40 50 60 70 80 90 100

Nötig

0 10 20 30 40 50 60 70 80 90 100

Figure B. *Example of a score sheet used by panelists in training and analysis.*

Appendix 6 – Complete Spider Plots

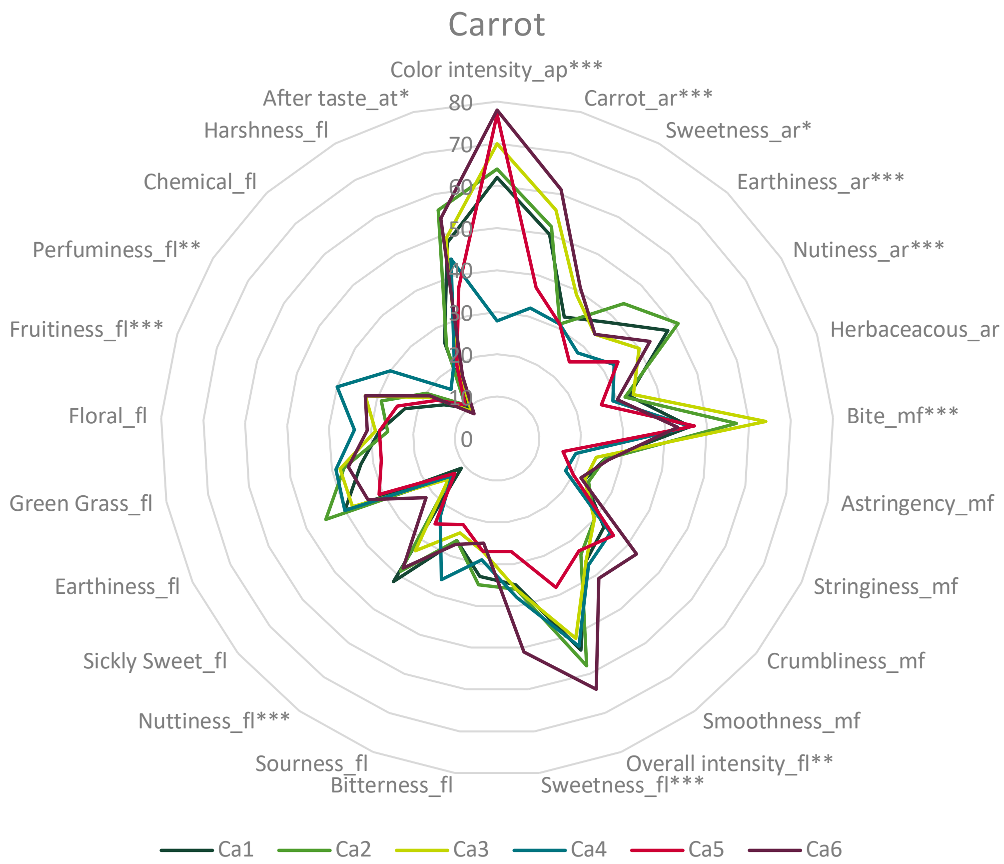

Figure C *Complete spider chart from analysis of carrot cultivars. The spider plots present the mean values of the attributes obtained by the panel for each cultivar, on a scale from 0 to 100. The attributes are marked with ar - aroma, mf - mouthfeel, fl – flavour and at – after taste.*

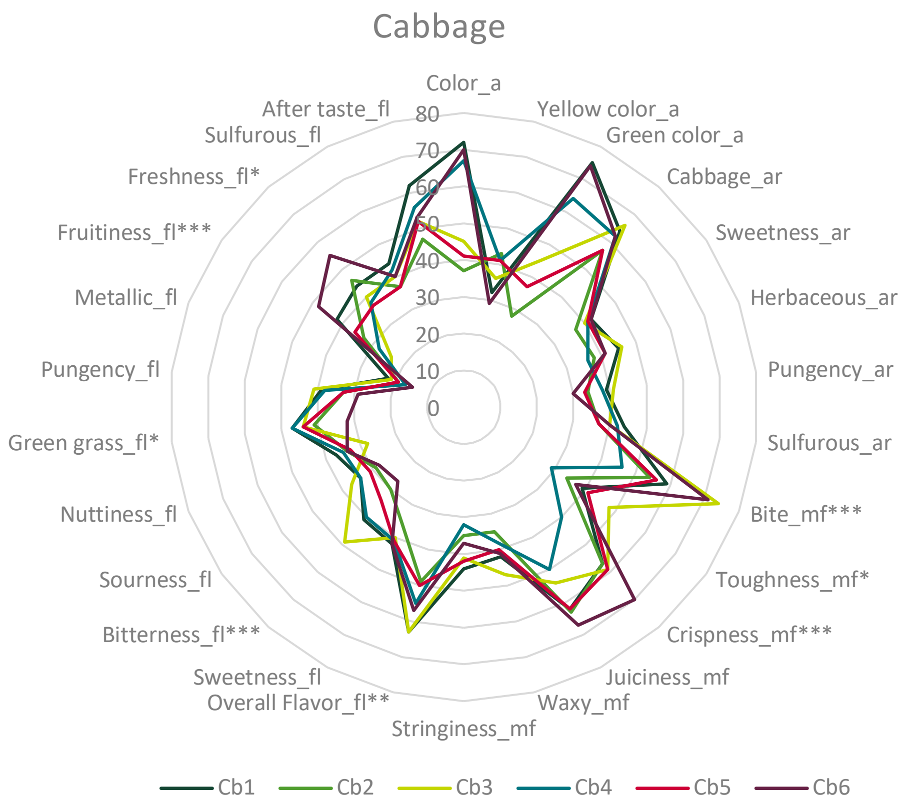

Figure D. *Complete spider chart from analysis of cabbage cultivars.*

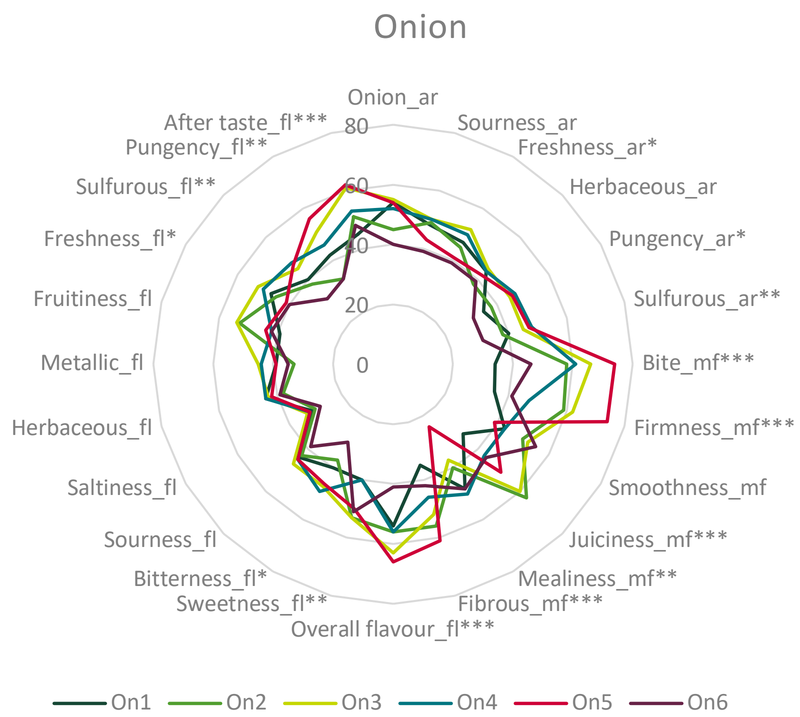

Figure E. *Complete spider chart from analysis of onion cultivars.*