New Concept Development of a Blood Glucose-Balancing Functional Beverage

Master Thesis by
Fiona

Academic Supervisor
Federico Gómez

Company Supervisor
Elin Östman

Examiner
Yvonne Grandfeldt

Department of Food Technology, Engineering and Nutrition

Lund University

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Popular Science Summary

For many years, type 2 diabetes mellitus (T2DM) has been one of the most common degenerative diseases. In addition, the prevalence is constantly increasing not only among the older people, but also in the younger generation. This fact is highly connected with the lifestyle and dietary habits, including the high consumption of refined carbohydrate which is more available on the market. In this case, a healthy diet, combined with regular exercise can be the alternative to prevent the development of T2DM.

Interestingly, the trend on healthy and nutritious food consumption is also constantly growing. It has a positive impact on the growth of functional food market with food products that offer some additional benefit beyond its nutritional value. Further, innovation on functional food is not only fulfilling the arising demand, but also offers more option on healthier products in the market.

Functional beverages can be considered as one of the most popular categories of functional foods. One example is Good Idea that is a sparkling water with addition of five essential amino acids and chromium picolinate and the aim to reduce the rise of blood glucose after a carbohydrate-rich meal. Under the claim '*may help those with normal blood sugar levels handle the sugar spike following a meal*', Good Idea wish to support and facilitate consumers effort to adopt a healthier lifestyle.

In order to cope with various market needs, continuous development of product varieties is important. This project focuses on a line extension of Good Idea. In order to get a natural addition of more nutrients to the product, infusing juice from Nordic berries to the recipe of Good Idea drink was targeted as the new product line. Several challenges are however associated with such a project. Not only should the original taste and nutritional values be fulfilled, but the additional benefits should be achieved at the same time. Utilization of fruit ingredients with the ambition to create a clean labelled-product, the challenges around formulation and the processing operation was the core of this thesis work. Additionally, a preliminary verification of the blood glucose balancing effect in a pilot human study was also done by using CGM (Continuous Glucose Monitoring).

Combination of apple, cloudberry, blackcurrant, and cranberry were chosen to be the main fruit components on the developed formulas. The result of the study shows a promising product character both from sensory and nutritional point of view. Although some reduction of vitamin C and changes on the colour upon heat treatment cannot be avoided, vitamin C and antioxidant properties from the fruits were found to be potential as additional benefits on top of the blood sugar regulating properties of the existing Good Idea drink. Moreover, through a focus group discussion and sensory evaluation, the developed formulas were all acceptable. Thus, this product concept and development have a great potential to put into account.

Abstract

Type 2 Diabetes Mellitus (T2DM) have known to be one of the most common degenerative diseases which highly correlate with lifestyle, including consumption habits. It cannot be denied that the availability and accessibility to high processed food, high in carbohydrates play an important role on increasing the risk of T2DM. On the contrary, consumers' awareness towards health and nutrition are also rising. These situations open the opportunity for food industries to develop more functional products which can give additional benefits and fulfil the consumers' needs.

Categorized as 'supplementary drink' in the U.S. market, Good Idea® came as a functional beverage with its blood-sugar regulating effect from the amino acids and chromium combination. A line extension was aimed to be done based on the existing product which were the flavoured sparkling water with the addition of amino acids and chromium. Natural ingredients were aimed to be introduced as the new concept of 'infused Good Idea®' which sourced from fruits, specifically by utilising Nordic berries.

Combinations of berries and some other fruits were tried during the development process, including some different types of fruit sources. At the end, fruit juice concentrate (FJC) was chosen as the fruit source which suited to most with the carbonated premix-base. Various fruits: mango, apple, cloudberry, blackcurrant, cranberry, sea buckthorn, lingonberry were evaluated to create the new fruit combination for the line extension. However, combination of apple, cloudberry, blackcurrant, and cranberry became the main fruit combination with addition of flavouring agent to sharpen the product character.

Some issues were identified on the development stage, such as unwanted stable foam formation, unpleasant colour, and acidity (sourness) level. These issues were then evaluated and solutions were provided. Since blackcurrant were identified as the cause of the unwanted stable foam formation, adjustment on the formula of the drink was done. Following the foam reduction, colour and acidity were also improved by adjusting the FJC combination on the formula which resulted on two final formulae with pH <3.90. Both formulas were evaluated based on the sensory properties through a focus group discussion (FGD) and hedonic sensory evaluation.

The product is aimed to be packed in cans with 355mL volume. Additionally, tunnel pasteurization 70°C for 30 minutes was decided as the heat treatment method as it was done on the existing product line. In this case, the effect of heat treatment was investigated towards some properties, such as colour and vitamin C content. The result shows that heat treatment produces a darker product due to anthocyanin degradation and non-enzymatic browning. Further, around 32-35% reduction of initial vitamin C were obtained as the impact of heat treatment. As a part of analysis, antioxidant capacity was investigated based on DPPH antioxidant capacity method. This method showed that all of the developed formulae have rather high potential antioxidant capacity, comparable with orange. High content of phenolic compounds on the berries might be the reason behind this result.

The new approach of meal study by using continuous glucose monitoring is quite promising and can be considered as an alternative from the traditional meal study. However, no firm conclusion can be drawn from the study due to some limitation, including the small number of research subjects. In this case, no significant difference was found on all of the incremental area under the curve (iAUC) within 0-120 minutes on all types of drinks with three different meals.

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List of Abbreviations

AA- Ascorbic acid

AEAC- Ascorbic Acid Equivalent Antioxidant Capacity

BC-Blackcurrant

CGM-Continuous Glucose Monitoring

CrPic – Chromium Picolinate

DPPH- 2,2-diphenyl-1-picrylhydrazyl

FGD-Focus Group Discussion

FJC- Fruit Juice Concentrate

iAUC-Incremental Area Under Curve

IC_{50}-Inhibitory Concentration

T2DM-Type 2 Diabetes Mellitus

1. Introduction

Type 2 Diabetes Mellitus (T2DM) have known to be a lifestyle related disease which can actually be prevented. Currently, about 1 out of 10 Americans have diabetes and approximately 90-95% of them have the T2DM. Not only that, more children, teens, and young adults are also developing it (CDC, 2019). According to Gross et al. (2004), this fact is highly supported with the high availability of processed food with refined carbohydrates. Studies showed that this rapidly digestible-fast-carbohydrates have high potential on causing the glucose excursions and insulin spikes which further led into the increase of oxidative stress and endothelial dysfunction (Humpert, 2010). These conditions are then identified to be related to the risk of T2DM development. To prevent, it is important to replacing refined carbohydrates with low-GI carbohydrates sources and high fiber diet (Gross et al., 2004).

At the same time, there has been a growing trend on the awareness of the role of food and beverages in disease prevention and treatment. These food and food components that provide a health benefit beyond basic nutrition are defined as functional foods in the US (Corbo et al., 2014). The increasing cost of healthcare, steady increase on the life expectancy, and the desire on improving quality of life have opened the opportunities for food industries to innovate and develop functional products (Bigliardi & Galati, 2013). Development of functional beverages is one of potential ways to deliver nutritional properties and flavours that can attract the consumers' interest. However, bioactive compounds, antioxidant capacity, and high quality of sensorial properties are not the only aspects to be considered. The challenge is to identify the optimal combination of ingredients with certain processing and preservation methods to ensure both the bioavailability of bioactive compounds and safety (Peña et al., 2016).

To fill the gap, Good Idea® came as a new approach on fulfilling the demand of functional beverage and preventing the risk of T2DM growth at the same time. Good Idea® is a functional beverage with a concept of sparkling water with added amino acids and chromium. More specifically, this product aimed to support and facilitate consumers' effort to live a healthier lifestyle by avoiding the high blood sugar responses after meals (Good Idea Inc., 2019).

Currently, Good Idea® have been marketed in the US with three different flavour (orange/mango, lemon/lime, and dragon fruit) packed in cans and in Sweden with lingonberry, lime/lemon, and blueberry flavours in PET and glass bottles. As a part of innovation, a new concept of Good Idea® aimed to be developed with additional benefits from natural ingredients. Additionally, the development concept is also closely connected with the current pandemic caused by COVID-19. This situation has led to the increasing needs and concern on health with respect to the growing interest on the improved nutrition and increased intake of immune supporting nutrients.

2. Objectives

This study aimed to develop a line extension of Good Idea® drinks for the US Market. The development should involve natural ingredients in the form of fruit sources that provides flavour, minerals as the source of electrolytes, and vitamins, aligned with the US legislation requirement. The product should be appealing in terms of colour, aroma, and taste, without losing its benefit on balancing blood glucose level which then is proved through a pilot human study. Furthermore, the developed formula also aimed to be relevant for scaling up purposes.

Specific aims

- To identify the problems and opportunities arisen from using fruit puré as the main ingredients;
- To identify problems and opportunities from using fruit powders and/or fruit juice concentrates as the main ingredients;
- To measure the product colour as part of the physical characterisation;
- To determine the ascorbic acid and DPPH antioxidant capacity of the products;
- To evaluate the acceptability of the products;
- To do a preliminary verification of pilot human study by using continuous glucose monitoring (CGM).

3. Theoretical Background

3.1 Good Idea® Drinks

Good Idea® is a sparkling water with addition of five essential amino acids and chromium picolinate which aimes to reduce the rise of blood glucose caused by a carbohydrate-rich meal. Furthermore, Good Idea® aimes to support and facilitate consumer effort for a healthier lifestyle. This product is currently categorized as dietary supplement on the US market, with "*may help those with normal blood sugar levels handle the sugar spike following a meal"* as a structure-function claim.

3.1.1 Good Idea® Premix

Five essential amino acids (L-Leucine, L-Threonine, L-Lysine, L-Isoleucine, and L-Valine) and chromium picolicate (CrPic) are the active ingredients in the proprietary Good Idea® premix. Clinical studies proved that having the the drink with a mixed meal resulted in a significant reduction of the serum blood glucose iAUC in healthy overweight subjects, compared to placebo (Östman et al., 2020). Although the exact mechanisms of the postprandial glucose are not completely clear, the amino acids have an insulin stimulatory effect and chromium induce the insulin interaction with its receptor through binding of a low molecular chromium binding protein (Cefalu & Hu, 2004).

It is known that amino acids are involved in the insulin secretion through their effect on β-cells (Gannon & Nuttall., 2010). The effect of individual amino acids is not as high as glucose in terms of provoking the insulin secretion *in vitro* whereas the combination of amino acids is known to be more effective. It was also found that, *in vivo*, amino acids from dietary proteins and the one released from epithelial cells may stimulate insulin secretion in combination with glucose (Newsholme et al., 2006).

Milk and whey protein are known to have the ability to stimulate insulin and hence reduce the postprandial glucose as response to a glucose solution (Gunnerund et al, 2012). A study suggested that the mechanism is related to the insulinogenic properties of whey protein that results in a hypoglycemic effect. Five amino acids: leucine, isoleucine, valine, threonine, and lysine; rise rapidly in the blood upon whey ingestion and reduce the postprandial glycemic response (Nilsson et al., 2007).

One study proved that supplementation of essential amino acids in the diet significantly improved the metabolic control and insulin sensitivity in poorly controlled T2DM subjects (Solerte et al., 2008). Moreover, based on clinical trials it was proven that a combination of leucine, threonine, lysine, isoleucine, valine and chromium would provide a synergistic effect on reducing 20-30% blood sugar rise or reducing postprandial glucose excursions following a carbohydrate rich meal without causing any disproportional insulin increase or any adverse events (Östman et al., 2020).

3.2 Fruits and Mixed Fruit Beverages

Consumption of mixed fruit-based beverages has increased significantly and has become one of the growing food sectors in the industry (Pzczola, 2005). Thus, such functional beverages are now an attractive and healthy source of hydration. As fruit juices are perceived as healthy and refreshing, incorporation of other ingredients with different bioactive compounds can be done to enhance the functional properties, making the product more attractive for consumers (Peña et al., 2016). In this case, berries and apple were chosen to be the combination of the fruits.

3.2.1 Berries

In general, berries are identified by the high content and varieties of phenolic compounds. Flavonoids, tannins, and phenolic acids are some of the wide varieties of phenolic compounds which stand out with their biological effects, including antioxidant and anticarcinogenic properties (Slatnar et al., 2012).

i. Blackcurrant

Blackcurrants (BC; *Ribes nigrum*) known to be small dark purple seed-containing berries with diameter up to 12 mm and grow from medium-sized woody shrubs (Gopalan et al., 2012). BC usually grow in colder climate areas, including northern Europe, northern and central Asia. In general, BC are characterized by their deep shades of purple colour with bitter and astringent flavour. This deep shade of purple colour is the result of a high level of polyphenolic compound, to be specific anthocyanin.

Aside from their polyphenol compounds, BC is also rich in ascorbic acid ranging in between 70-280 mg per 100 g fresh fruit. Hence, BC is also known to have strong antioxidant effect from the ascorbic acid contribution. It is known that BC also contains high levels of minerals such as potassium, calcium, magnesium, and iron (Gopalan et al., 2012). These minerals play important roles in normal growth and preventing some chronic diseases, including atherosclerosis and its complication (Goristein et al., 2001). With those health and therapeutic reasons, the interest on BC consumption has increased in recent years (Cosmulescu et al., 2015).

The chemical composition of BC may vary, depending on the environment and genetics of the plant which affect its nutritional composition and production. The type of BC cultivar affects the concentration of polyphenol compounds. High temperature during the growing of BC is associated with the decrease of the ascorbic acid concentration due to the inhibition of some biochemical processes during the growth of BC fruits. Additionally, decrease of flavanol and anthocyanin compounds may also occur (Cortez & Mejia, 2019).

ii. Cranberry

Europe, Asia, and North America are known to be the source of European cranberry. Usually, August and September are the months where these berries become ripe with pink, red, or dark red colour. These berries are known to have strong acidic flavour with pear or egg-shaped, round, oval, or cylindrical shape. The trend on their bioactive compounds' utilization is constantly growing, supported by their folk utilization as medicines in Eastern Europe, Finland, Sweden, and Russia (Jurikova et al., 2018).

European cranberries are rich in phenolic compounds, such as anthocyanins, flavonoids, and phenolic acids. The berries are also packed with high level of organic acids and vitamin C. Depending on the cultivar, those compounds may result on wide variation of the bioactive compounds. More specifically, variations in cultivation condition, region, weather, harvesting time, and maturity stage result on the difference of the accumulation level of phenolic compounds. Other than the condition of raw berries, processed cranberries may also have some flavonoids content variation due to the processing procedures (Blumberg et al., 2014).

iii. Cloudberry

Cloudberry (*Rhubus chamaemorus*) or 'hjortron' in Swedish is a small woody perennial dioecious species which is mainly found in bog on mountain areas. In Europe, cloudberry is mainly found in Russia, Norway, Sweden, and Finland. Although cloudberries can be produced in large quantities, they are still considered as a high-priced commodity due to the difficulties to access their growth areas. The berry fruit itself consist of 4-20 edible drupelets with red colour during unripen stage and soft orange at the maturity stage (Nilsen, 2016).

It is known that cloudberry can be eaten fresh or frozen, or further processed as jams, wines, liqueur, sweets, and syrup. Fruit and herbal tea are also common to be made from cloudberry due to its high vitamin C content. To retain their vitamin C, cloudberries are usually being frozen or preserved immediately after picking. Aside from vitamin C, cloudberry is also rich in vitamin E, antioxidant compounds such as phenolic, anthocyanins, phenolic acids and their esters. Amongst all, ellagitannins/ellagic acid is the dominating variety (Martinussen et al., 2010). These properties known to be beneficial to prevent high blood pressure and improve blood circulation (Li et al., 2015). Similar to other northern berries, cloudberries are one of the sources of carotenoids with the high level of β-carotene and lutein (Lashmanova et al., 2012). Additionally, cloudberries also packed with micro-nutrients such as Fe, Cu, Mn, Zn, Mg, K, Ca, and P (Thiem, 2003).

iv. Apple

Apple is one of the most widely grown fruits in the world where some cultivars are grown specifically for the use in the processing and the rest are used for fresh market. To ensure the quality, only sound and ripe apple should be further processed to prevent the quality deviation due to decay, damage, maturity, firmness, colour, soluble solids, acids, and tannins of the fruit. Like other fruits, climate and soil may affect the harvested apples (Bates et al., 2001). Additionally, cultivar, ripening, storage, and processing may affect the phytochemical quality of the apples (Boyer & Liu, 2004).

Different cultivars of apples result in different taste profile. Generally, the red apples perceived to have better taste than the green due to the higher sugar and flavour contents. In the case of unpeeled apple, red apples are sweeter while the green apples are more acidic and sourer with grassy descriptors. The peeled version of red apples is described as sour while the green is described as sweeter (Arshad et al., 2014).

Although apple provides some amount of vitamin C and potassium, it cannot be the source of both compared to other fruits. However, it is known that apple is a good source of soluble fiber which can contribute to the control of insulin levels by slowing down the release of sugar into the bloodstream (Lee 2012). Other than that, according to epidemiological studies, apples play an important role in reducing the risk of some chronic diseases and maintaining health in general. In relation to that, apple has been used as the source of flavonoids in the daily diet in both Europe and the US. Compared to other fruits, apples had the highest level of free phenolics which made it higher in availability for the absorption into the bloodstream (Boyer & Liu, 2004).

3.3 Carbonated Beverages

3.3.1 Carbon Dioxide and Carbonated Beverages

Carbonation is defined as the incorporation of carbon dioxide gas to a liquid phase. Carbonation gives an enhancement of flavour and refreshing sensation. Moreover, it also provides enjoyable taste and “pleasurable and sought after’’ sensation for most consumers. (Thongrote et al., 2016).

Carbon dioxide is a type of colourless and odourless gas which is slightly heavier than air, with a density of 1.98 kg m^{-3} at 298 K. Through compression and cooling, this gas can easily be liquefied. As a water-soluble gas, the solubility of carbon dioxide is increasing with the reduction of media temperature (Ashurst, 2016). Carbonic acid will be produced as soon as this gas is dissolved in water and results in an acidic character and biting taste or known to be tingling in aroma and mouthfeel sensation (Martínez-Lapuente et al., 2018).

CO_2 has an effective preservation capacity which can supress the growth of yeast which can produce metabolite gas. In addition, it also has effective properties against mould spoilage due to the low amount of oxygen presence. Although addition of carbon dioxide may ensure that the pH level is low enough, to avoid unwanted growth of pathogenic microorganism, the formulated product needs to have a pH value below 4.0 (Ashurst, 2016).

One of the most commonly used carbonated beverages pasteurization procedures is tunnel process or tunnel pasteurization. This technique usually involves passing a filled and closed product through a chamber. Inside the chamber, heated water will be sprayed as the transfer medium until the product temperature gradually rises (typically around 70 °C) within 20 minutes. This process is then finished by lowering down the products into an ambient temperature through cooling water spray (Ashurst, 2016).

3.3.2 Incorporation of Fruits

As the trend of carbonated beverages is increasing, carbonated fruit juice may become a new concept of beverage which can provide nutritional elements from the fruits, natural colour, and flavour, together with sparkle or effervescence effect (Thongrote et al., 2016). Reconstituted juice mainly contains between 2 and 10% of fruit juices concentrates. In this case, incorporating fruit juice to become a carbonated beverage may cause potential problems where any particles from the juice can result on unwanted nucleation point. Further, it may affect the release of CO_2 once the container is open and gas pressure is released and may cause the product to be gush out uncontrollably from the package (Ashurst, 2016).

3.3.3 Foam and Bubbles

In carbonated beverages, effervescence is defined as the generation and growth of a large number of bubbles that rise to the surface of the liquid and break up after a while. This bubble is known to be a small gas globule which is separated from its liquid environment (Viejo et al., 2019). Furthermore, packed gas bubbles can create liquid foams within a liquid matrix (Drenckhan & Saint-Jalmes, 2015).

The formation of foam and stability of bubbles are related to the surface tension which is known to be the force per unit area that maintains the bond between the molecules on the surface of the liquid (Buxaderas & López-Tamames, 2010). A stable bubble layer can be formed through the presence of surfactant which can reduce the surface tension of the liquid. For this reason, the foam formation and persistency depend upon the chemical composition of the liquid as well as the interaction amongst the foam active compounds. One example is regarding the foam quality and stability in the sparkling wine which is affected by the protein, total amino acids, polysaccharides, anthocyanins, and polyphenol composition (Martínez-Lapuente et al., 2018).

Foam is considered to be relevant in beverage production, since it may lead to a quality and safety issue during the bottling or filling process. Overflowing of foam may pollute the bottle and filling equipment which may further lead into not desired additional costs and time for cleaning. Due to the foam formation, additional space in the bottle or packaging is needed to ensure the intended volume is achieved. In addition, there is also a risk where the filling volume may not be reached and cause product losses (Bates et al., 2001).

3.4 Processed Fruits Used for The Manufacturing of Beverages

3.4.1 Fruit Puree

Fruit juice can be defined as puree when the consistency of the fluid pours very slowly or defined as pulp when it pours even more slowly and behaves as pseudo-plastic with Herschel-Bulkley flow model (Gundurao et al., 2011). Fruit puree or pulp are often used as an ingredient for processed food where the quality needs to be consistent. This requires standardization of the physico-chemical properties of the puree. Some of the important parameters are colour, flavour, rheological properties, as well as thermo-physical properties (Guerrero & Alzamora, 1998). To increase a sufficient amount of total soluble solid content and to slightly reduce the pH to enhance the shelf life, sugar is often added.

3.4.2 Fruit Powder

As a method of preserving fruits, reducing moisture content and water activity can be done through drying. Among the drying techniques, spray drying is one of the commonly used methods to produce dry powders and agglomerates. In spray drying, the liquid product is atomized in a hot current to obtain a powder form (Phisut, 2012). Thus, fluid materials can be transformed directly into solid or semi-solid particles. This technique is known to be applicable for heat-sensitive products due to the short drying time, reduce temperature, and rapid water evaporation which result in a better product quality (Santana et al., 2018).

To produce fruit powder, concentrated juice needs to be used to have higher content of solids, hence lowering the amount of liquid needed to be evaporated in the dryer. The challenge with this method is the low glass transition temperature (Tg) of the fruit due to the low molecular sugars (sucrose, glucose, fructose) and some organic acids (Santana et al., 2018). The powder may become sticky, hygroscopic, with problem in solubility. These problems are usually solved by addition of carrier agents (maltodextrin, gum Arabic, modified starch, protein) before the juice concentrates being dried (Muzaffar et al., 2018). Another way to solve the problems is by using a carrier agent such as polymers and gums for microencapsulation which also can preserve the flavour and aroma of the product (Phisut, 2012).

3.4.3 Fruit Juice Concentrate

Fruits are perishable commodities and their quality can easily be deteriorated due to the environmental or enzymatic factors. Fruit juice concentrates are one way to preserve juices for longer time under simplified storage conditions. Due to its high sugar content, concentrate can be stored without being cooled. To produce specific quality and quantity of the concentrates, it is possible to adjust some factors such as the type of fruit, degree of maturity, pre-treatment and juice processing, including the ratio between fiber and pulp. By transforming fruits into concentrates, transport and distribution of fruit materials become easier as well as lower in cost (Bermu´dez-Soto, & Tom´as-Barber´an, 2004).

One of the most common techniques is the evaporation of fruit juice under ambient pressure or vacuum condition to produce pumpable juice concentrate. Usually, the single-strength juices are boiled under vacuum condition and thus the water phase can be evaporated. By this technique, both water content and water activity of fruit juices will be lowered. The challenge of evaporation using heat is to prevent huge loss of the fruit nutrients (vitamins, flavonoids). Hence, minimum heat treatment is more desirable (Adnan et al., 2018).

Depending on the type of fruits and intended quality of the concentrate, evaporation can be done in either single or multiple effect evaporators. Some fruits such as apple, pineapple, and grape can be concentrated five to seven times while more pectin-rich fruits like mango is usually concentrated only two to three times. Some fruits are also more heat-sensitive thus the evaporation technique and temperature need to be considered to achieve the targeted final brix concentration. The final quality of concentrated fruit juices is monitored based on physicochemical parameters such as colour, acidity, pH, viscosity, as well as the amount of soluble solids (brix), starch, and pulp (Adnan et al., 2018).

3.5 Antioxidant Properties of Fruits

Antioxidants are stable molecules which can donate their electron and neutralize a free radical compound through its radical scavenging properties. This action leads into the reduction of the free radical capacity that causes cellular damage. In human tissues, antioxidants prevent the formation of radicals, scavenge free radicals or promote the decomposition of free radicals as their mechanisms of defence (Lobo et al., 2010). Excess of free radicals in comparison to antioxidant defences may lead into oxidative stress. This condition is highly associated with inflammatory diseases where an excess of oxidative stress can further lead into the oxidation of lipids and proteins and changes within their structures and functions (Rao et al., 2006).

In general, some antioxidants are produced through normal body metabolism while others are sourced from the diet, including vitamins such as vitamin C and E. Consumption of antioxidant-rich food have been studied in relation to their potential to prevent some diseases (Ioannou et al., 2020). One of them is flavonoid-rich food which is mainly sourced from plants, where berries, cherries, citrus, prune, and olives have been found to have strong antioxidant activities. These properties are usually found in the form of flavonoids. As part of phenolic compounds, flavonoids may act as potent antioxidants and metal chelators and play important roles such as anti-inflammatory, antiviral, and anticarcinogenic (Lobo et al., 2010).

In food applications, raw materials are mainly transformed by being processed and mixed together with other ingredients. Since antioxidant activity is highly affected by temperature, light, oxygen, and pH, food processing may result on the changes of flavonoid structure and further lead into changes on their antioxidant capacity (Ioannou et al., 2020). Heating in general can cause the acceleration of the initiation reaction and thus decrease the antioxidant activity due to the faster utilisation of the antioxidant. Furthermore, with the lower antioxidant activity, the ability of reacting with free radicals become lower as well (Reblova, 2012). This process however may differ depending on the flavonoid types, food matrices, and processing condition (Ioannou et al., 2020).

3.5.1 Ascorbic Acid

Ascorbic acid or vitamin C plays important roles for various biochemical and physiological processes in the body. Together with vitamin B, it is classified as a water-soluble vitamin and also recommended to be supplied from the diet in order to support normal physiological functions. It plays an important role on cholesterol conversion to become bile acids and lowering the blood cholesterol levels (Chambial et al., 2013). Vitamin C helps the synthesis and metabolism of some essential amino acids, together with its function as a cofactor for human enzymes. Furthermore, vitamin C also acts as an antioxidant which protect the body by scavenge potentially harmful free radicals (Granger & Eck, 2018). With these functions, vitamin C have been widely used in the treatment and prevention of a number of disorders such as common cold, atherosclerosis, and heart diseases (Chambial et al., 2013).

Severe deficiency of vitamin C may result in scurvy and many other deficiency symptoms in relation to the function of vitamin C as enzyme cofactor. In this case, recommended daily allowance (RDA) of vitamin C is regulated and the value widely differs across the world (Granger & Eck, 2018).

Fruits and vegetables are known to be a rich source of vitamin C. However, the amount of vitamin C may differ depending on the cultivar and growing condition. On the other hand, it is also a temperature-sensitive vitamin and an easily oxidized acid. These characteristics makes it easily degraded through cooking or processing with elevated temperature and long-time (Lee et al., 2018).

4. Experimental and Development Overview

Preliminary Development

Phase 1: Fruit Puree	- Existing formulas: A, B, C, D - Issue & opportunity identification
Phase 2: Fruit Powder	- Ingredient solubility and characteristic evaluation
Phase 3: Fruit Juice Concentrate	- Ingredient solubility and characteristics evaluation

Further Development

Phase 3.1: Fruit Juice Concentrate Formula Development	- Formula development: A.1, D.1 - Evaluation of formula A1 and D1
Phase 3.2: D.1, D.2, and D.3 Formula Development and product characterization	- Foam Identification and reduction - pH, brix - colour measurement - vitamin C analysis - DPPH antioxidant capacity
Phase 3.3: D.2, and D.3 Product acceptance	- Focus Group Discussion - Sensory Analysis

Pilot Human Study

CGM data collection	- iAUC analysis

5. Materials and Methods

5.1 Raw Materials

The original Good Idea® premix, which consists of amino acid-CrPc was provided from Sternvitamin (Germany). Fruit purees, fruit powders, and juice concentrates were provided by both Kiantama Oy (Finland), Döhler (Germany), and Wrams Aroma (Sweden). All fruit purees were in January 2021 and kept in the freezer (-18 to -20 °C), while the juice concentrates were received in March 2021 and kept in the freezer. Flavouring agents were provided by Einar Willumsen AB (Sweden and Denmark) and kept at room temperature.

5.2 Method for Making Infused Good Idea® Drink

On the laboratory scale, the drinks were made by dissolving the weighed Good Idea® premix with warm water (60 °C, 20 minutes) by using magnetic stirrer. The mixture then cooled down until it reached 7-10 °C before being carbonated. In the meantime, the juice concentrates and flavouring agents were weighted and mixed with addition with 10% (from the amount of product) uncarbonated premix water. The carbonation process was done by using Soda Stream (SodaStream®, Sweden) with 3-5 times CO_2 infusion by slowly pushing the trigger button until it produced sound, followed by releasing the pressure slowly afterwards. The juice concentrates mixture was then mixed with the carbonated premix water until it reached the intended volume.

In the commercial scale production, the drink is being packed into aluminium cans and being heat treated at 70 °C for 30 minutes by using tunnel pasteurizer. For the laboratory scale, a water bath was used to mimic the heat treatment process by using the same temperature and time.

5.3 Preliminary Trials and Development

5.3.1 Phase 1: Fruit Puree

Preliminary development was recipes developed in a previous student project (unpublished). All of the formulae were based on the original Good Idea® premix as the base for the addition of fruit purees. None of the formulae were utilizing food additives such as stabilizers and flavouring agents. The fruit combinations were done as reported below in Table 1. For each recipe combination, pH and brix were measured.

Table 1. Fruit puree combination

Formula	% Fruit Puree Combination
A.1	4.0% cloudberry + 1.0% sea buckthorn + 2.0% mango
B.1	3.5% cloudberry + 2% lingonberry
C.1	3.5% rosehip + 1.0% sea buckthorn
D.1	2.5% blackcurrant + 0.5% cranberry + 3.0% apple

The aim of the preliminary development study is to identify challenges that should be addressed from the previous recipe and to identify the most promising combination from both technical and sensory aspects through lab trials and internal sensory evaluation.

5.3.2 Phase 2: Fruit Powders

As an alternative for the fruit puree, the use of fruit powders was tested. Powdered fruits were available in broader fruit varieties with higher nutrition and fibre contents. Moreover, the material handling and storage were considered to be simpler. The fruit powders of rosehip, blackcurrant, cranberry, and sea buckthorn that were tested were '100% fruit powder', without any additional additives (e.g., maltodextrin). According to the product specifications, the fruit powders were spray dried and still have some amounts of dietary fibres. Thus, mechanical blending is needed to be able to dissolve them in water.

5.3.3 Phase 3: Fruit Juice Concentrates, Further Development of Juice Concentrate formulas

Fruit juice concentrates (FJC) were evaluated to substitute the other fruit alternatives. FJC were pasteurized by the supplier and stored in the freezer. From the formulae reported in Table 1, not all fruits could be found as FJC in the market. Thus, only formulae A.1 and D.1 were tested using FJC with the same % as it was used in the form of fruit puree. Initially the formulae were modified based on a targeted content of vitamin C. The aim is to reach at least 6% RDI of vitamin C theoretically before the product is heat treated. For safety reasons, the end pH of the drink should also be below 3.9. Other than that, taste, colour, and aroma were also being the main considerations during development of the new formula by using FJC. Additional flavouring agents were being introduced to each of the recipes. The aim was to strengthen the flavour and aroma characters of the drinks.

Similar to the treatment of fruit puree, FJC was easily dissolved by stirring it with water before being carbonated. For each recipe combination, pH and brix were measured. Both recipes were then evaluated based on their sensory properties and scale up opportunities.

5.4 Foam Identification and Evaluation

A stable foam was formed on the formula (D.1) which may cause technical issues during carbonation and filling steps in an industrial setting. Moreover, the foam may also be perceived as unpleasant by consumers. In this case, apple, BC, and cranberry JC were evaluated by infusing 1.0% of each FJC with carbonated premix base. The FJC that produced foam then evaluated by making series of different concentrations: 1.0, 1.5, 2.0, 2.5, and 3.5 % and infused them to both carbonated water and carbonated premix-water. The foam volume in each concentration were then calculated by considering the diameter and thickness of the foam layer formed. Further, the % of foam formed were calculated by comparing the foam formed with the total volume of the diluted FJ in the carbonated base.

5.5 Nutritional Composition, pH, and Brix

Nutritional composition was calculated based on the raw ingredients' specification provided by the suppliers. The detailed result is not included in this report due to industrial confidentiality. Calibration of each instrument was done prior to the actual product measurement. pH of each formula was measured by using a pH meter (Mettler Toledo FP20) while brix was measured by using a refractometer at room temperature (Wine Refractometer HI 96811).

5.6 Colour Measurement

To analyse the colour of each formula and evaluate the impact of heat treatment (pasteurization 70 °C, 30 min), colour measurements were done on formula D.1 and the developed formulas (D.2 and D.3) both before and after being heat treated. The sample was prepared twice, being each preparation done from scratch. The measurement was done in triplicates (n=3) for each sample.

The colour measurement of each sample was done by using colorimeter (Konica Minolta CM-600D, Japan) which was previously calibrated. The calibration was done twice, with zero and white calibration. The zero calibration was done by directing the sensor to a free surface while the white calibration was done by using white cap on the sensor. Each calibration was done by pressing the calibration button and 5 measurements were done automatically.

L*, a*, b* colour system was used on this instrument. L* scale represents the lightness of the colour from black to white ($L^* = 0 – 100$), a* scale represents the colour range between red (+) and green (-), while b* scale represents the colour range between yellow (+) and blue (-) (Wuttisin & Boonsook, 2019). The total difference of the whole colour system was calculated as ΔE where the result usually lies between 0-100, by using the following equation:

$$\Delta E = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{½} \qquad \text{Equation 1}$$

5.7 Vitamin C

The analysis method was based on Zanini et al. (2018) with modifications. The method was based on fluorometry, which measured the vitamin concentration through the reduction of potassium permanganate. In this reaction (shown in Equation 2), potassium permanganate is consumed by the presence of vitamin C which is indicated by the reduction of its violet colour. This reaction causes the reduction of absorbance at 525nm.

$$2KMnO_4 + 5C_6H_8O_6 + 3H_2SO_4 = 2MnSO_4 + 5C_6H_6O_6 + K_2SO_4 + 8H_2O \qquad \text{Equation 2}$$

Potassium permanganate ($KMnO_4$) 100mg/L was previously prepared by dissolving it in sulphuric acid (H_2SO_4) 0.1 mol/L. A standard curve of ascorbic acid, ranging from 1, 5, 10, 15, and 20 mg/L were made by diluting 100 mg/L ascorbic acid stock solution. Reduction of the absorbance was then measured by reacting 10 mL of diluted sample or standard solution with 10 mL of potassium permanganate solution (0.1 M). The reduction of absorbance was calculated based on Equation 3**.**

$$\text{Reduction of absorbance} = \text{A blank} - \text{A sample} \qquad \text{Equation 3}$$

Blank was obtained by reacting 10 mL of distilled water to replace the sample with 10 mL of potassium permanganate solution. The reaction was followed in a PerkinElmer spectrophotometer (Lambda™ Bio+, U.S).

The sample was prepared twice, being each preparation done from scratch. The measurement was done in duplicates (n=2) for each sample. The concentration of ascorbic acid on the samples was calculated as mg/L by using the linear equation from the standard curve. The final concentration was then converted into mg/100mL by dividing the mg/L ascorbic acid value by 10.

5.8 DPPH Antioxidant Capacity

Antioxidant capacity was evaluated by the DPPH assay according to Brand-William et al. (1995) with modifications. The antioxidant compounds from the samples will scavenge the DPPH and the reduction of DPPH is monitored by the decrease of the absorbance at 515 nm. The purple colour in the initial solution turns to yellow when the full amount of the free radical is blocked by the antioxidant. The reaction was followed in a PerkinElmer spectrophotometer (Lambda™ Bio+, U.S).

The sample was prepared twice, being each preparation done from scratch. and the absorbance of each sample was read in duplicates (n=2). For the measurement, a series of sample concentration ranging from 45 000, 50 000, 55 000, and 60 000 μg/mL were made by diluting 10 000 μg/mL sample stock solution in methanol. In addition, ascorbic acid (AA) was used as the standard. A range of concentration of AA from 40, 60, 80, to 100 μg/mL were made by diluting 100 μg/mL ascorbic acid stock solution in methanol.

For each concentration, 0.1 mL of the solution was mixed with 3.9 mL methanolic DPPH solution (6×10^{-5} mg/L) and kept on the dark for 30 minutes. The decrease of absorbance was measured at 515 nm. The percentage of the radical scavenging activity is calculated from the equation:

$$\% \text{ Scavenging activity} = [(A0 - A1)/A0] \times 100 \qquad \text{Equation 4}$$

where *A0* is the absorbance of the control (0.1 mL of distilled water in in 3.9 mL methanolic DPPH) and *A1* is the absorbance in the presence of the sample

The percentage of DPPH remaining against the sample or stock concentration (mg/mL) was then plotted to obtain the amount necessary to decrease the initial DPPH concentration by 50 % (IC_{50}). Furthermore, the final antioxidant activity of the samples was expressed as the ascorbic acid equivalent antioxidant capacity (AEAC) as mg AA/100 mL sample by calculating:

$$AEAC = IC_{50}(AA)/IC_{50}(sample) \times 10^5 \qquad \text{Equation 5}$$

5.9 Focus Group Discussion

A focus group discussion was conducted on two final recipes (D.2 and D.3). The aim of the focus group discussion was to evaluate the final recipes characteristics and to evaluate the level of acceptability before conducting a final sensory evaluation. Two final recipes (D.2 and D.3) were evaluated with four internal panellists from Aventure AB, which included people of both genders, both EU and non-EU citizens with age range of 23-60 years old. All panellists were already familiar with the Good Idea® product concept and were neither involved in any development work nor tried the latest recipes before. Questions regarding to product concept and preference were asked before and after they tried both products and the answer were discussed in the group (see Appendix IV).

5.10 Sensory Evaluation

A sensory evaluation was performed to evaluate the consumers preference on formula D.2 and D.3. Thirty untrained panellists from both genders participated with age range from 20-60 years old, both EU and non-EU citizens. Sensory parameters such as colour, aroma, taste, sourness level, and overall acceptance were evaluated on both formulas by using an evaluation form (see Appendix V).

5.11 Preliminary verification of concept and human study

A pilot concept of human study developed where new technology was applied to evaluate the blood glucose regulating properties of food and meals in a free-living situation. In this case, frequent sampling of blood glucose was done 24 hours per day for 10 days by using Continuous Glucose Monitoring (CGM) devices instead of the traditional meal studies. With this method, the research subjects would neither need to repeatedly visit the study facility, nor spend several hours every time to collect blood from fingertip and/or arm vein.

This pilot study was carried out on 6 people who met certain inclusion criteria to make sure the they did not have increased fasting glucose levels or insulin resistance. During the assessment of the subjects' eligibility, fasting blood glucose samples were collected and determined directly by using the HemoCue Glucose 201 system (HemoCue, Ängelholm): The result had to be below 6.0 mmol/L to meet the study requirement. Further, venous blood samples from the arm were taken to determine the serum insulin levels (analyzed by Skåne University Hospital, Medicinsk service - Labmedicin).

The serum samples were taken from a cannula into a gel SST vacuum tube, centrifugated (4000 rpm, 10 minutes), and transferred to false bottom tubes which were frozen (-18 °C) before being submitted for analysis. By using both blood glucose and serum insulin results, Homestasis Model Assessment of Insulin Resistance (HOMA-IR, fasting glucose in mmol/L x insulin in mIU/mL)/22.5) was calculated as a gross measurement of insulin resistance. The value for the participants had to be below 2.5 to be included in the study.

Some additional criteria were need to be fulfilled by the research subjects, such as the BMI limits of 25-29.9 kg/m^2, no antibiotics consumption or not engaged in weight loss for 3 months before the study. Information related to the occurrence of diabetes in the immediate family was also collected and written consent collected from each research subject. The study was approved by the Ethical Review Board of Sweden under D-number 2021-01438 and registered at clinicaltrials.gov under NCT04848233.

The research subjects applied the blood glucose meter on themselves in the morning on the first day of the experiment. During the first day, they began to register their meals and activities to get acquainted with the smartphone application. The following days were then divided into three groups of three days, when identical meals were eaten for all 3 days and only the drink was varied. The same drinks were included at breakfast, lunch and dinner within each day and in total, three different drinks were tested. From this scheme, data was collected for 3 repetitions of the same meal with each of the three different drinks, and each drink was tested with 9 different meals. The breakfast, lunch, and dinner meals were provided in the form of commercially available products with a known composition of carbohydrates, fats, and proteins. At the end of the 10th day, the blood glucose meter was removed and the experiment was completed.

The three drinks used in this pilot study was the original version of Good Idea® (Lingonberry flavour)− later stated as ‘control positive’, a Good Idea® extension variety with formula D.2−later stated as ‘infused’, as well as a lingonberry flavored drink without amino acids and CrPic (Placebo). On this report, three types of breakfast meals were used: oatmeal, pancake, and sandwich (see Appendix VI).

5.11.1 Continuous Glucose Monitoring (CGM)

The CGM (Dexcom G6, San Diego, CA, USA) works by inserting the sensor under the subjects’ skin on the belly or arm by using a one-touch applicator. The device contains a sensor which continuously measures the glucose levels beneath the skin and wirelessly sends the data which transmitted to a connected mobile application. Thus, the device was need to be connected with the mobile application provided by the manufacturer. Another smartphone application, Nutrisense.io (Chicago, IL, USA) was used for meals and activity registration, including physical activity and sleep. Blood glucose values were also uploaded to the Nutrisense app and at the completion of the study, all data was exported to the principal investigator.

5.12 Statistical Analysis

GraphPad Prism 9.1.1 (GraphPad, U.S) was used to perform the iAUC calculations and draw the blood glucose curve. Additionally, results of most analyses were analysed based on one-way analysis of variance (ANOVA) which performed using SPSS 27 (IBM, U.S). The results were compared using Duncan’s test with $p<0.05$ as the significance level. To analyse the sensory evaluation result, independent sample t-test was performed by using the same software.

5.13 Project Limitations

In the development process, no standardization of the carbonation level could be done due to lack of equipment. In addition, no pasteurizer was available for the heat treatment step. To overcome that, a water bath was being used as the alternative, possibly introducing deviations in terms of heat and temperature distribution compared with the commercial product. For the pilot human study, the Placebo drink was not heat treated at all. Additionally, no canning facility was available, hence no packaging test was done with the product. As an alternative, manual filling and packaging in PET-bottles was used for the pilot human study. Due to the time limitation, the pilot human study was still ongoing when compiling this report and hence no complete data can be presented.

6. Result and Discussion

6.1 Preliminary Trials

6.1.1 Phase 1: Fruit Purees

From the lab trial, some technical issues were identified. The thick and bulky character from the pulp of fruit purees made some of the substances precipitate after some time. This precipitation made the flavour and taste of the final drink (carbonated) uneven and stronger on the bottom. It also got a rather unappealing visual appearance as shown in Figure 1. It was hypothesized that without adding any additives (e.g., stabilizer), it was difficult to create a well distributed fruit puree on the drink.

Flavour and aroma were also crucial aspects to be improved. These formulas, did not include any flavouring agents, which resulted in weak aroma and taste of the blended fruit purees. All recipes had pH ranging between 3.7-3.9, so there was no need for any acidifier in the recipes to reach the targeted pH.

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Figure 1. Fruit puree-based formula A.1, B.1, C.1, and D.1 (left to right)

From an internal sensory evaluation towards a preference of the formulae, 33.33 % panellists chose formula A.1, B.1, and D.1 respectively. However, based on the availability on the ingredient alternatives to replace the fruit puree, uniqueness of fruit composition, along with the nutritional composition preference, formula A.1 and D.1 were decided to be developed further.

6.1.2 Phase 2: Fruit Powders

The fruit powders could not be completely diluted in the premix-based water. Most of the fruit powder particles precipitated quickly and produced a colour gradient between the surface and the bottom, as can be seen in Figure 2. As a result, both taste and aroma from the fruit powders were neither strong nor well blended. Since the fruit powders were poorly dissolved, no further development was done by using this ingredient.

Figure 2. Sea buckthorn powder (left) and cranberry powder (right)

The other option of the fruit powder was the spray dried fruit powder with addition of maltodextrin. This option may have a better solubility. However, it is not the most preferable alternative since it would increase the calorie contribution to the drink, which should be avoided.

6.1.3 Phase 3: Fruit Juice Concentrate

Based on the evaluation, FJC were identified for having the best solubility compare to both fruit puree and fruit powder. Hence, FJC was decided to be the fruit ingredient to be used further. In this case, based on the fruit composition uniqueness and FJC availability, formula A.1 and D.1 were chosen to be developed further by using FJC to replace the fruit puree

i. Combination of cloudberry, sea buckthorn, mango (Formula A.1)

The sea buckthorn juice that is being used contained a thin layer of oil and pulp particles. Although manual sieving was done to reduce the pulp, precipitation upon heat treatment still occurred. Hence, a smaller sieve may be needed. Due to the oil content, a thin layer of oil was formed on the surface of the formulated drink both before and after heat treatment. This unwanted layer of oil may affect consumer preference and thus need to be minimized. To overcome, other treatments such as oil separation or extraction would be needed by also considering the risk of nutrients and flavour loss.

Another challenge was related to the changes in sensory properties due to the heat treatment. There were some obvious changes upon taste and aroma, where an over-cooked sensation could easily be detected. Additionally, the heat treatment also caused changes in the colour resulting in a dull and unattractive yellow colour. These unwanted changes might be able to reduce by modifying the heat treatment, using a higher temperature and shorter time.

ii. Combination of blackcurrant, cranberry, and apple (Formula D.1)

Some issues were detected in formula D.1. First, the colour was extremely dark and strong colour intensity was present both before and after the heat treatment. This colour could easily be perceived as unattractive and not representing the freshness of the drink. Secondly, a stable thick layer of foam was produced. This layer may lead to unattractiveness from the sensory point of view, as well as technological problems in the production facility, specifically in the filling step. On top of that, from the taste perspective, this formula was too acidic and astringent with confectionary-like aroma.

From these issues, adjustments and further development were needed to improve the formula. Intensity of the colour needed to be adjusted aiming at lighter and more attractive colour. On the other hand, foam formation needed to be reduced as much as possible without compromising taste and flavour. This formula was considered to be more technologically feasible with the facilities, resources, and time availability in comparison with formula A.1. Furthermore, only one drink could be added to the pilot human study. Thus, it was decided to only move forward with the development of formula D.1.

6.2 Development and Improvement of formula D.1

6.2.1 Foam

As mentioned above, an unwanted layer of foam occurred on formula D.1, especially when producing volumes > 1 L. The foam formed was quite stable and lasted for a long time in both refrigerator (4 ºC) and at room temperature. Moreover, technical issues may occur during the upscaling to a bigger production capacity, where the foam may overflow during the filling step. Identification of the FJC which caused the foam formation was done. As the recipe contained blackcurrant, cranberry, and apple, each of the single FJC were evaluated in both carbonated water and carbonated premix-base.

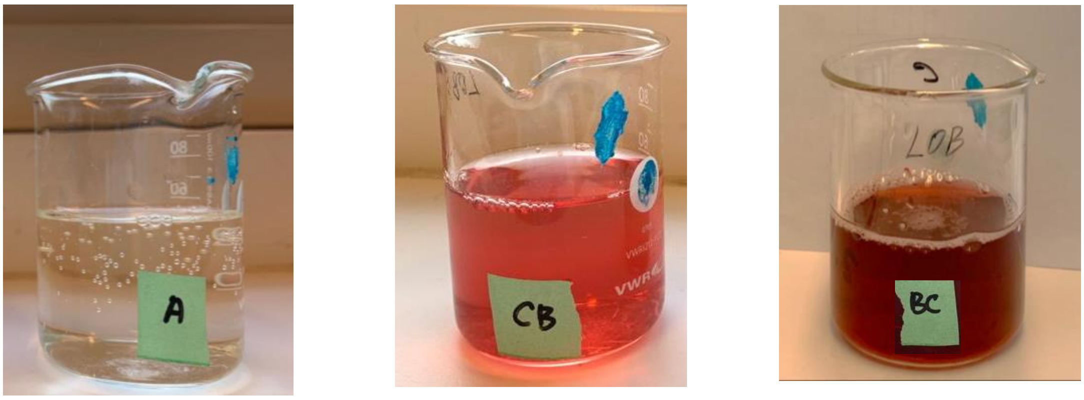

Figure 4. 1.0% FJC in carbonated premix-base water: Apple (A), Cranberry (CB), and Blackcurrant (BC)

From Figure 4, it can be seen that blackcurrant juice concentrate produced the foam, while no obvious foam was formed from both cranberry and apple juice concentrate. Based on this evaluation, the foam mostly occurred on the mixture between blackcurrant JC and carbonated premix-base as shown on Figure 5 below.

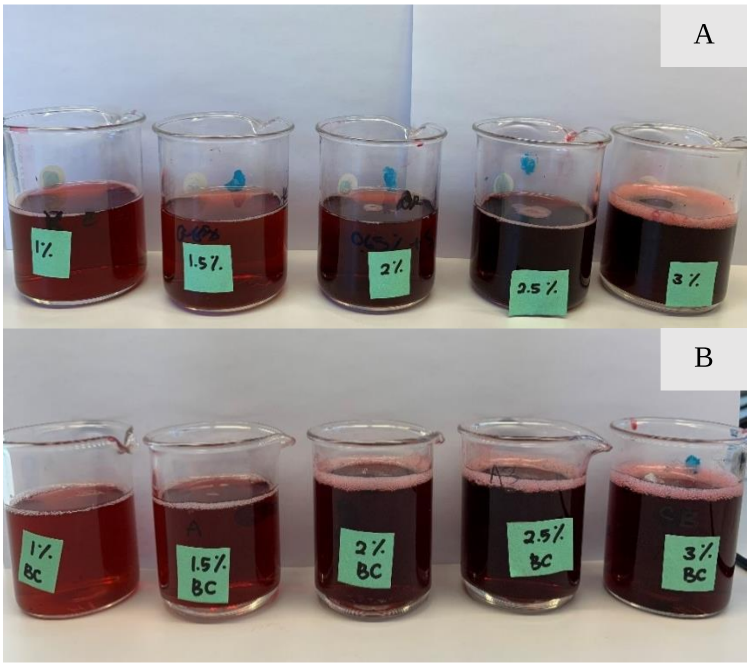

Figure 5. Foaming test for blackcurrant JC in (A) carbonated water and (B) carbonated premix base

From these observations, the foam mainly occurred when the blackcurrant JC was mixed with the carbonated premix-base. As shown in Figure 5B, the foam volume is increasing as the concentration of the FJC increased. Additionally, all foam formed was long lasting both in room or fridge storage temperatures. The formation of foam in carbonated premix-base may relate to the polyphenols content of blackcurrant, which according to studies, are able to stabilize the structure of protein. It has been reported that the foam formed from blackcurrant protein-polyphenol particles improved the foam stability in comparison to whey protein isolate alone (Foegeding et al., 2017).

Some other studies also mentioned that free amino acids may act as foaming agents. At wine pH (3.0-4.0), amino acids act as surfactant with both hydrophilic and hydrophobic groups. Further, the amino acids will be retained in the air/liquid interface, reducing the surface tension and increasing the foaming ability (Martínez-Lapuente et al., 2018). In this case, the Good Idea® premix contains five essential amino acids and hence it can be hypothesized that the behaviour may also be similar to the free amino acids when it comes to foam formation and stability. Since the premix-base will be used for the Good Idea® drink, the volume of the foam on the carbonated premix-base was estimated and calculated as shown in Table 2.

Table 2. Foam formation at different juice concentrations in the carbonated premix-base

% Blackcurrant juice concentrate	% Foam
1.0	2.36±1.15[a]
1.5	5.11±1.69[a, b]
2.0	8.45±2.08[b, c]
2.5	10.06±0.15[c]
3.0	15.37±0.63[d]

*different letter on the same column indicates significant difference ($p<0.05$)

The amount of foam formed when 3% blackcurrant JC was used was significantly higher than the foam formed when other concentrations were used. Thus, a reduction of the blackcurrant JC in recipe D.1 was needed. The aim was to generate as little foam as possible in the drink. From Table 1, 1.0 and 1.5% concentration of blackcurrant JC produced the least foam with no significant differences between them. To reduce the risk on further foam development when scaling up production, the 1.0% concentration was chosen to be used in the final formula.

6.2.2 Nutritional Composition, pH, Brix

All formulae were developed based on the existing Good Idea® premix as the product base and FJC were infused as additional ingredients. Based on the previously developed formula (see section 5, Table 1), D.1 decided to be improved further. The improved formulae (D.2 and D.3) were developed by considering the foaming test results, also the taste and colour as the important sensory characteristics. In addition, nutritional content, specifically of vitamin C, was also taken into consideration. The improved composition is provided in Table 3 and the nutritional composition is provided in Appendix 1.

As the improved formulae, both D.2 and D.3 have only 1.0% BC JC according to the foaming test. To compensate the nutritional value, produce a balance taste and reduce the sourness and astringency, adjustment on the apple JC and addition of cloudberry JC were done. Additionally, these combinations are also result on brighter product colour.

Table 3. FJC combination on each formula

Ingredients	Formula (% w/w)	
	D.2	D.3
Apple JC	3.5	3.5
Cloudberry JC	2.0	2.5
Blackcurrant JC	1.0	1.0
Cranberry JC	0.5	0.5
Flavouring agent	0.045	0.045

Both pH and brix results can be seen on Table 4. It is shown that all formulae have a pH below 3.90 which was aligned to the targeted value. From the pH, it can be seen that significant differences ($p<0.05$) were obtained from the three formulae. In this case, formula D.1 was significantly lower in pH while formula D.3 has the highest pH value. The low pH value on formula D.1 was one of the reasons of the high acidity and astringency taste of the drink that was detected during development stage, compare to D.2 and D.3.

Table 4. pH and brix of each formula

Formula	pH	brix
D.1	3.58±0.01[a]	5.43±0.12[a]
D.2	3.72±0.01[b]	5.43±0.58[a]
D.3	3.75±0.01[c]	6.27±0.58[b]

*different letter on the same column indicates significant difference (p<0.05)

Besides pH, brix value of each formula was also measured. The result shows that formula D.3 has the highest brix value (p<0.05) while no difference was obtained between the brix values of both formula D.1 and D.2. With relatively higher pH and brix, sourness of the drink may perceive lower in comparison to the other formulas. This result may correspond to the addition of cloudberry FJC and reduction of blackcurrant FJC in both formula D.2 and D.3.

6.2.3 Colour Measurement

Colour is one of the most important product properties as it plays an important role in forming consumers impression of the product. In this project, it was desired to have a product with natural colour provided from FJC which also needed to be appealing and represent freshness of the drink. Changes may take place during heat treatment and thus colour was measured to evaluate the effect of heat treatment on the colour of the drink.

Table 5. Effect of thermal processing on colour

sample	L*	a*	b*	ΔE
D.1	4.42±0.14[a]	0.53±0.22[a]	-0.71±0.25[b]	1.97±0.57[a]
D.1 Heat	2.44±0.65[a,b]	0.46±0.19[a]	-0.63±0.11[b]	
D.2	11.20±1.85[d]	1.53±0.40[a]	-0.66±0.05[b]	8.79±0.68[b]
D.2 Heat	8.54±0.58[c]	9.03±0.60[b]	1.75±0.06[c]	
D.3	6.07±0.09[b]	1.24±0.09[a]	-1.46±0.3[a]	7.81±0.47[b]
D.3 Heat	4.90±0.22[b]	7.97±0.97[b]	1.60±0.07[c]	

*different letter on the same column indicates significant difference (p<0.05)

It was detected that heat treatment (pasteurization 70 °C, 30 min) caused changes on the colour of all the formulae. Although all formulae decreased their lightness value (L*), only formula D.2 had a significant change (p<0.05) as shown in Table 5. On the other hand, heat treatment increased the greenness (a*) and the blueness (b*) in formulae D.2 and D.3 significantly (p<0.05). However, a non-significant decrease of a* and an increase of b* value took place in formula D.1 (p>0.05). These changes were closely correlated with the pigment composition of the fruits.

Anthocyanins was one of the dominating pigments in the berries that were used in the drink. Heat treatment, specifically pasteurization, is known to cause the decrease of anthocyanin content of juice. Although each berry may have different anthocyanin composition, colour stability is more affected by the total anthocyanin content rather than the composition (Rein & Heinonem, 2004). Thus, it can be concluded that different total anthocyanin content on each formula may lead into different degree of colour stability after heat treatment.

A similar result was obtained by (Kruszewski & Zawada, (2021) where pasteurization in 90 °C for 1 minute caused an increase of the blueness level of blackcurrant fruit juice. Non-enzymatic browning of the fruits was hypothesized to be the reason behind this change Additionally, a small decrease of L* and increase of a* indicated some colour shifting towards dark red. In addition, other studies on grape juice concentrate showed that decrease in L* value and increase in both *a and b* may happen as a result of anthocyanin destructions and the occurrence of Maillard reactions during heating in the juice concentration process (Maskan, 2006).

According to Maskan (2006), ΔE represents the total difference of the colour changes where the higher value indicates significant change in colour from the reference by considering L*, a*, and b* values. With 1.97±0.57 value of ΔE, formula D.1 have the least colour changes during the heat treatment ($p<0.05$). On the other hand, both formulae D.2 and D.3 have no significant differences in ΔE value between each other. Although formulae D.2 and D.3 have higher ΔE compared to formula D.1, the values are still in the range of ΔE between 2-10 and hence all indicate 'perceptible at glance' perception. However, with significantly lower value, perception of colour changes on formula D.1 may be perceived as 'perceptible through close observation' as the ΔE lies between 1-2 (Github, n.d.). Figure 7 shows the visual appearance of all formulae, both prior and upon heat treatment.

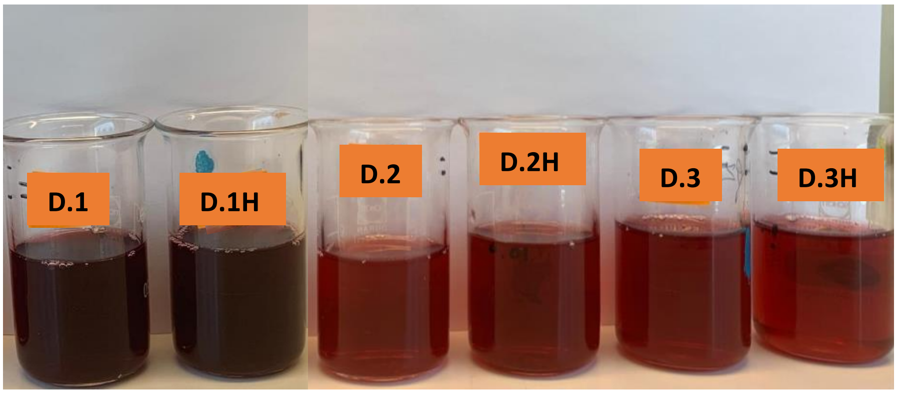

Figure 6. Formula D.1, D.2, and D.3 before (right) and after (left) heat treatment, where "H" means "heated"

6.2.4 Vitamin C

Due to the nutritional composition of the fruits used in the drink, vitamin C was targeted as one of the beneficial nutrients to provide to the consumer. In this case, no additional vitamin or mineral was added besides the one which are naturally present in the FJC. For the formulae development, the vitamin C level was aimed to at least reach 6% US RDI (100% RDI = 90mg) in the initial formula without any heat treatment. To fulfil 6% of RDI, at least 5.4 mg/100mL of vitamin C needed to be achieved initially by combining the FJC in certain proportions without putting aside the sensory properties, such as taste and colour.

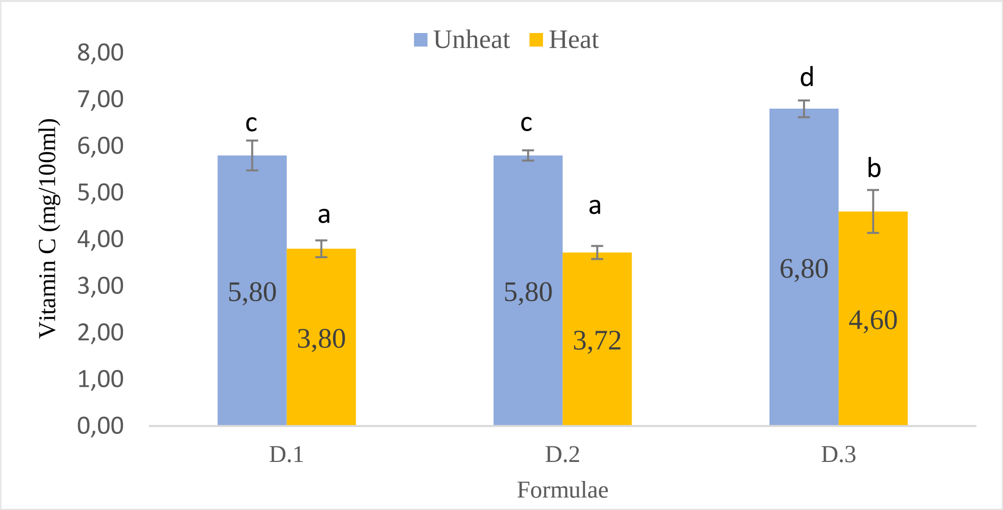

Figure 7 The vitamin C content of each formula, composition of each formula is given in Table 3. Different letters indicate statistical significance

Figure 7 shows that each formula reached the initial target of vitamin C, and that formula D.3 had the highest vitamin C content with (6.80±0.18) mg/100 mL ($p<0.05$). On the other hand, both formulae D.1 and D.2 had around 1.0 mg/100mL lower vitamin C content compared to formula D.3. In this case, a higher total of FJC composition in formula D.3 contributed to higher vitamin C content in the final product.

Changes in the content of vitamin C were identified after pasteurization, where degradation took place due to the heat treatment. Results show that all formulae had vitamin C degradation ranging between 32 to 35%. This degradation reduced vitamin C in each formula significantly ($p<0.05$). Reduction of vitamin C during heat treatment was aligned with the finding from a study of pomegranate juice. It was mentioned that 30.30% of vitamin C content in pomegranate juice was loss due to 70°C heat treatment for 90 minutes (Paul & Ghosh, 2012). From the same study, it was also concluded that the ascorbic acid loss is increasing with time and processing temperature.

This spectrophotometry analysis method was chosen based on the simplicity and availability of the resources and instrument. Although the analysis results had good reproducibility, some interference might have influenced the results. According to a study, it was found that the reducing sugars in fruit juice interferes with the quantification of the vitamin C and overestimates the result with about 10%. This finding is highly related with the nature of potassium permanganate as the chemical on the analysis, is a strong oxidant which possibly reacted with the reducing sugar, apart from the vitamin C (Zanini et al., 2018). In order to produce more reliable results with lower interferences, HPLC analysis is highly recommended.

6.2.5 DPPH Antioxidant Capacity

Antioxidant capacity of the drinks were measured after the product was heat treated. The DPPH antioxidant capacity analysis is presented on Table 6. The antioxidant capacity is expressed as AEAC (mg/100mL) where a higher value means a higher antioxidant capacity. From the analysis, it was found that formula D.1 have significantly higher antioxidant capacity compared to formula D.2 and D.3 with 173.405±1.12 AEAC (mg/100mL). On the other hand, both formulae D.2 and D.3 have no significant differences in antioxidant capacity between each other.

Table 6. DPPH antioxidant capacity analysis result

Formula	AEAC (mg/100mL)
D.1	173.405±1.12[a]
D.2	136.86±3.49[b]
D.3	142.93±3.15[b]

*different letter on the same column indicates significant difference ($p<0.05$)

One of the main contributors to antioxidant capacity is ascorbic acid (vitamin C). A similar study was done by Yan et al. (2006) on an orange, which also known to have quite high amount of vitamin C. The study found that the antioxidant capacity of the orange was 70±17 AEAC (mg/100 g). Even though this value was measured on solid fraction, by assuming 100 g equal to 100 mL, it can be concluded that all of the drink formulae have higher antioxidant capacity than an orange fruit.

It is shown that formula D.1 have the highest antioxidant capacity. Interestingly, no significant difference was found on the vitamin C content of formula D.1 and D.2. It can be hypothesized that the antioxidant capacity is not only contributed by vitamin C, but also other phenolic compounds, such as anthocyanins in berries and other phenolic compounds in apple. Different composition of each formula, such as higher content of BC FJC might result on the higher antioxidant content on formula D.1. Furthermore, formula D.1have no cloudberry on the composition, unlike formula D.2 and D.3. From this analysis, it can be concluded that all the formulas have good antioxidant capacity with potential to give additional benefits to the product.

6.2.6 Focus Group Discussion

The product concept "fruit juice-infused Good Idea®" was perceived as an interesting concept. By having Nordic berries, the product is expected to be unique and not as common as the usual berry drink that has been in the market. It is also expected to be sourced from the real and high-quality berries. In addition, this product concept may also be a potential representative of Nordics taste. For the non-EU participants, they found both lingonberry and cloudberry as not very common berries which made the product more interesting and distinct. On the other hand, the Swedish panellist have more expectations towards the taste of the drink.

Sensory characterization was conducted to identify the perception of some parameters, such as colour, aroma, taste, flavour, and overall properties as displayed in Table 7. From the comments, both formulas have pleasant perception for the colour which indicates an improvement from the previous formula (D.1) which has high and dark colour intensity. In terms of aroma, formula D.2 was perceived as more sweet-sour and berry like while formula D.3 was perceived as more sweet-berry like. According to the panellists, formula D.2 tasted a little bit sour with refreshing sensation and match the appearance of the product. On the other hand, formula D.3 was perceived as sweeter and sharper astringency, but less refreshing at the same time. Formula D.2 had more hint of cloudberry and 'currant' taste according to some of the panellist. In comparison, formula D.2 have more 'currant'-berry flavour while formula D.3 have weaker strawberry-like flavour.

Table 7. Panellist's comments on focus group discussion

Formula	Colour	Aroma	Taste	Overall
D.2	Pleasant and appealing red, represent freshness	Sweet and sour, berry-like	Little bit sour, refreshing, and light.	More rounded, balanced, and refreshing

D.3	and berries, not too intense, clear/not dull	More strawberry-like	Sweeter, sharper astringency, heavier, and less refreshing	Heavier in taste and less refreshing. Can be consumed as a social drink.

From the comments for each of the sensory attributes, formula D.2 is more preferable with more rounded and balanced overall taste and refreshing sensation. It was also concluded that the overall properties of formula D.3 might be more suitable as a social beverage rather than a functional 355mL beverage. As the aim of the drink is to become 'a drink with a meal', they considered that formula D.2 is more suitable and has more potential. In conclusion, both formulas have potential and are worth to be evaluated in a larger sensory evaluation.

6.2.7 Sensory Evaluation

Sensory evaluation was done as further evaluation of the consumers perspective towards formula D.2 and D.3. Both samples were labelled with three-digit numbers code and a neutral wafer and water were served to neutralize their palate. Consumer's preference of some parameters such as colour, aroma, flavour intensity, taste, and sweetness of the products was evaluated. Additionally, preference for consuming the products with a meal was also evaluated.

It was found that there were no significant differences despite the cloudberry content difference on formula D.3, except on the taste, where D.3 got a higher rating. The evaluation summary of each parameter can be seen on Figure 8.

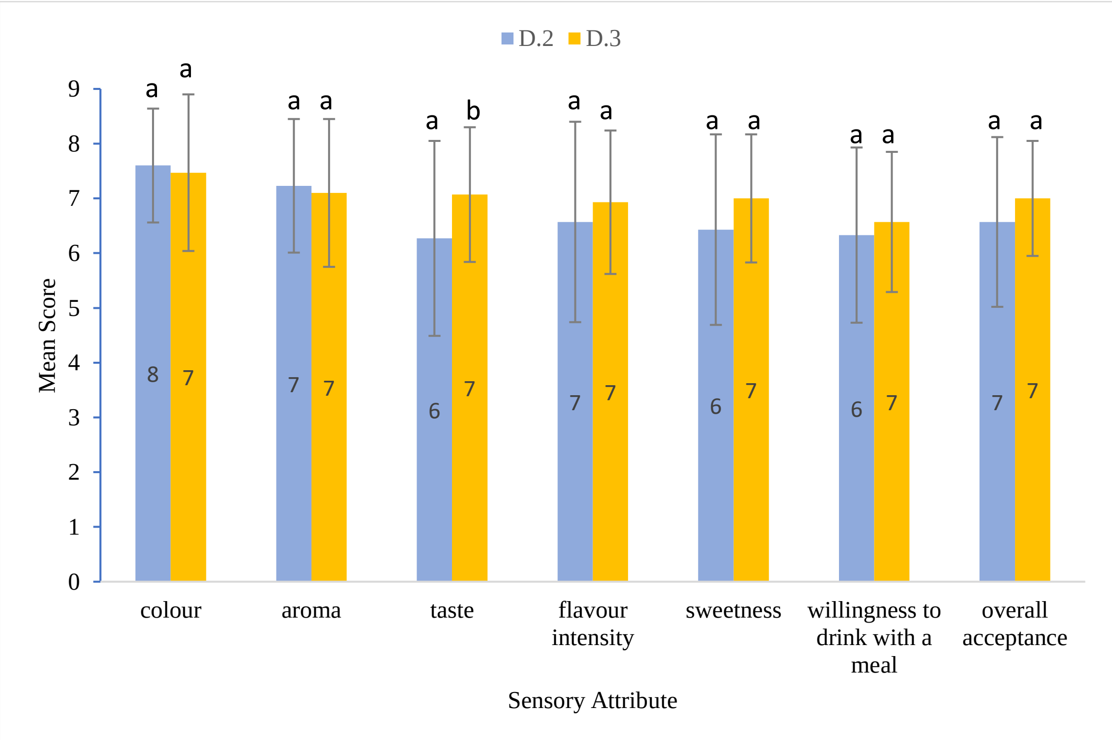

Figure 8. Sensory attribute evaluation towards formula D.2 and D.3
Different letters represent significant difference ($p<0.05$) on the same sensory attribute

i. Colour Preference

Formula D.2 and D.3 scored 8 and 7 respectively without any significant difference ($p>0.05$). These scores can be defined within the range of 'like moderately' to 'like very much' and were in agreement with the FGD result where the colour of both formulas was perceived as clear and pleasant. It can be seen that the higher content of cloudberry in formula D.3 did not give significant effect on consumers' colour preference. On the other hand, some panellists also perceived that the colour was slightly similar to commercial soda which may give unhealthy associations.

ii. Aroma Preference

No significant difference ($p>0.05$) was found on the aroma preference for both formulas. The consumers scores can be defined within the range of 'like moderately' with a score of 7 for both D2 and D3. In this case, no suggestions were provided as a feedback from the panellists.

iii. Taste Preference

A significant difference ($p<0.05$) was found on the taste preference where formula D.2 had lower score (6) which defined as 'like slightly'. On the other hand, formula D.3 had higher score (7) which is more likely to be defined as 'like moderately'. These results indicate that the higher cloudberry content in formula D.3 produced a taste difference which could be detected by the consumers. Interestingly, these results were also in contrast with the FGD result where formula D.2 was more preferable in terms of taste. The difference of preference and broader panellist profile may have influenced this result.

iv. Flavour Intensity

Although the taste was perceived as different between both formulas, no significant difference ($p>0.05$) was found on the flavour intensity preferences. As displayed on Figure 8, both scores were relatively similar and defined as 'like moderately'.

v. Sweetness Preference

No significant difference ($p<0.05$) was found on the sweetness scores for both samples. Although 'somewhat sour' and 'a bit too sour' were mentioned on the feedback section, the sweetness level of both samples can be defined in between 'like slightly' and 'like moderately' by the panellists. It can be concluded that the sweetness of the drinks was still acceptable.

vi. Willingness to Consume with a Meal

The preference to consume the drinks with a meal were both scored similarly as can be seen on Figure 8 where the score can be defined as 'like moderately'. In addition to that, to get more reliable data, an evaluation with the actual product serving size (355mL) with a meal was suggested by some panellists.

vii. Overall Acceptance

No significant difference ($p>0.05$) was found on the overall acceptance of both formulas. The scores defined as 'like moderately' with formula D.3 perceived as sweeter and more familiar according to some feedback. Interestingly, 64.5% of the panellists preferred formula D.3 as their favourite product in comparison to formula D.2.

6.2.8 Preliminary Verification of Concept and Human Study

The postprandial glucose responses to the three test drinks served with different breakfast meals are presented in Figure 9. No significant differences ($p>0.05$) were found for the iAUC 0-120 min when having the different drinks with the same meal. The delta mean values curves of iAUC of each breakfast meal can be seen on Appendix VII.

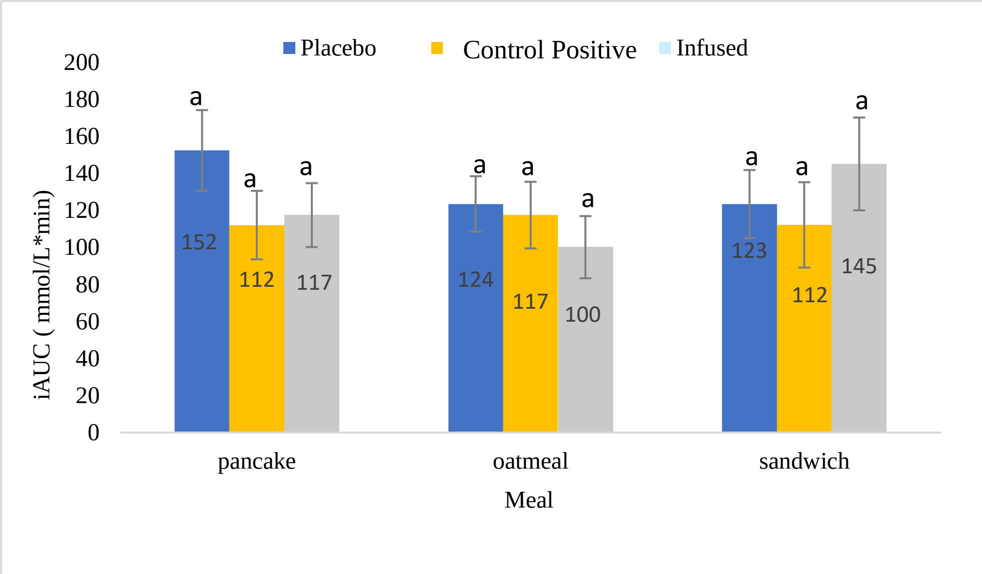

Figure 9. Glucose iAUC 0-120 minutes

*different letters indicates significant difference (p<0.05) on the same meal

Results presented as mean ± SEM (n = 6, except for n=5 for pancake/infused and n=5 for oatmeal/positive control)

This is the first time that postprandial blood glucose responses have been reported from CGM measurements. Unfortunately, some data points are missing due to lost contact between the sensor and transmitter. This impact of this issue would be reduced with a greater number of subjects. With the current number of participants, the variation between results makes it more challenging to draw firm conclusions. However, in comparison to the normal meal study, this CGM method may offer possibilities to study the effects of repeated intake of glucose lowering products on 24-h glucose variability. Furthermore, it is not excluded those postprandial differences between test products can be found if a larger number of participants is included.

7. Conclusions

Among the fruit purees, fruit powders, and FJC as the fruit sources for the Good Idea® line extension concept, FJC was the ingredient providing the best results. FJC was identified to have good solubility in water and stability as well as providing attractive colour, taste, and some beneficial nutritional compounds. To be specific, combinations of apple, cloudberry, blackcurrant, and cranberry were chosen for the formulae to be developed and further investigated.

Heat treatment (pasteurization) caused changes on the product's colour. The main changes were the decrease on the lightness and an increase on both greenness (more-red) and blueness (more-yellow) levels. It was found that the total changes were considered low with ''perceptible through close observation' and 'perceptible at glance'.

Heat treatment affected the vitamin C content. Due to its heat sensitivity, 32-35% reduction of vitamin C was obtained from the heat treatment for all formulae. Although the vitamin C amount decreased, the final amount still provided additional nutrition to the consumer. This beneficial nutrition was also enriched with the potential antioxidant capacity.

Both evaluated formulae (D.2 and D.3) resulted on a positive evaluation from all the sensory properties of the final formula. However, a difference on overall preferences was identified. It was found that formula D.2 was more preferable according to 4 panellists on the focus group discussion session, while formula D.3 was more preferable according to 64.5% of the 30 sensory evaluation panellists. From these results, it can be concluded that both formula D.2 and D.3 have potential to be further developed as part of the new concept of the Good Idea® drink.

No firm conclusion can be made from the pilot clinical study. From the analysis, no significant difference was found on the iAUC of the drinks from 0-120 minutes on the six subjects with three different meals. Thus, more research subjects are needed to have a more reliable conclusion.

8. Further Research Opportunities

In order to develop the product further, a trial with larger volumes is recommended, since most of the development was done in lab-scale. Firstly, parameter standardization towards the mixing of the FJC needs to be evaluated, such as mixing time and speed. Secondly, carbonation, packaging, and heat treatment using the actual can packaging and tunnel pasteurizer are highly recommended to be tested. In this case the sensory properties might be affected and hence, a further sensory evaluation with selected carbonation level and heat treatment would be valuable. Moreover, it is also recommended to have U.S consumers as panellists to get more representable data for the targeted market.

A more complete analysis on nutritional properties of the final drinks is highly recommended. HPLC is preferable for measuring vitamin C. Moreover, further studies regarding the phenolic compounds, anthocyanin to be specific, will be valuable for investigating the antioxidant properties deeper. Since most of the nutritional components may be affected by both heat treatment and storage condition, a shelf-life study based on nutritional compound reduction as well as sensory deviation are also important aspects to be evaluated.

Further, the result can be beneficial as an alternative for a simpler meal study method. More research subjects are highly recommended to perform more reliable data and trend. Additionally, backups for the CGM device sensors are needed and more standardized production of the product for the human study will also beneficial.

9. Acknowledgement

Years ago, a little girl dreamt about working in a chocolate factory. Then, she grew and figured out that food is something she passionate about and want to work with as much as she can.

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"Orang-orang itu telah melupakan bahwa belajar
tidaklah melulu untuk mengejar dan membuktikan sesuatu,
namun belajar itu sendiri, adalah perayaan dan penghargaan pada diri sendiri."

- Andrea Hirata-

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11. Appendix

Appendix I Nutritional composition

Formula D.1

Nutrients	per 100mL
Energy (kJ/kcal)	59.89/14.21
Carbohydrates (g)	3.45
of which sugar (g)	2.71
Fat (g)	0.02
Protein (g)	0.06
Fibre (g)	0.22
Vitamin C (mg)	5.8 (6.4% of RDI)
Phosphorus (mg)	2.04
Iodide (µg)	0.04
Iron (mg)	0.02
Calcium (mg)	1.88
Potassium (mg)	11.29
Copper (mg)	0.00
Magnesium (mg)	0.74
Sodium (mg)	0.10
Selenium (µg)	0.00
Zinc (mg)	0.01
Chromium (mg)	8.6 (22% of RDI)

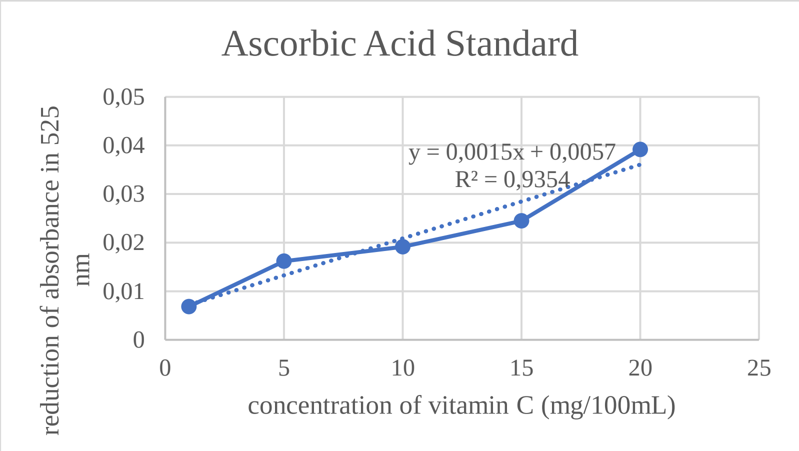
Formula D.2

Nutrients	per 100mL
Energy (kJ/kcal)	66.26/15.74
Carbohydrates (g)	3.74
of which sugar (g)	3.30
Fat (g)	0.04
Protein (g)	0.09
Fibre (g)	0.25
Vitamin C (mg)	5.8 (6.4% of RDI)
Phosphorus (mg)	1.39
Iodide (µg)	0.02
Iron (mg)	0.03
Calcium (mg)	1.15
Potassium (mg)	9.88
Copper (mg)	0.00
Magnesium (mg)	0.98
Sodium (mg)	0.12
Selenium (µg)	0.00
Zinc (mg)	0.02
Chromium (mg)	8.6 (22% of RDI)

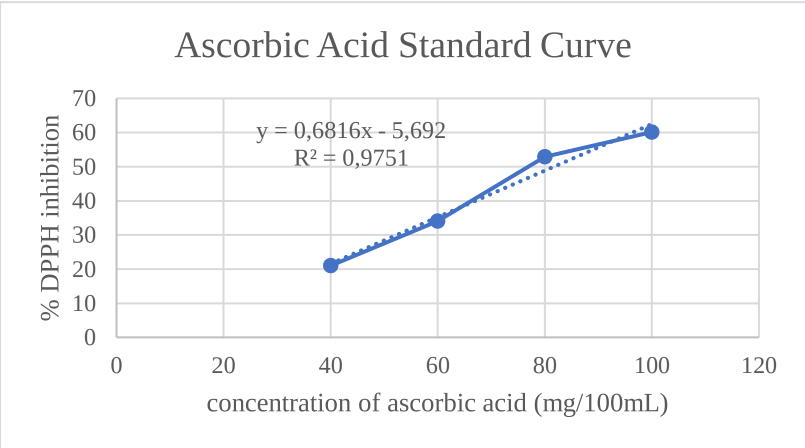
Formula D.3

Nutrients	per 100mL
Energy (kJ/kcal)	70.2/16.67
Carbohydrates (g)	3.95
of which sugar (g)	3.50
Fat (g)	0.04
Protein (g)	0.10
Fibre (g)	0.28
Vitamin C (mg)	6.8 (7.6% of RDI)
Phosphorus (mg)	1.49
Iodide (µg)	0.03
Iron (mg)	0.03
Calcium (mg)	1.22
Potassium (mg)	10.83
Copper (mg)	0.00
Magnesium (mg)	1.12
Sodium (mg)	0.14
Selenium (µg)	0.00
Zinc (mg)	0.02
Chromium (mg)	8.6 (22% of RDI)

Appendix II Standard curve of ascorbic acid concentration



Appendix III Standard curve of DPPH antioxidant capacity



Appendix IV. Focus Group Discussion

1. What do you think about the new concept of “Infused-Good Idea® with Nordic Berries”?
2. What is your expectation towards the word “Nordic Berries”?
3. What do you think about the colour of the samples?
4. What do you think about the aroma of the samples?
5. What do you think about the taste and the flavour?
6. Overall, what is your thought about each sample?
7. Which sample do you prefer the most?

Appendix V. Sensory evaluation form

Good Idea® Tasting Session

You’re about to taste a series of Good Idea’s future variant for the US market. The fruit juices used in various combinations are: blackcurrant, cranberry, cloudberry and apple. Before you taste, rinse your palate by drinking the water. After you finish with one sample, please rinse your palate by eating the wafer and drinking the water before continue tasting the other sample.

1. Age
   - <25
   - 25-39
   - 40-65
   - >65

2. Nationality
    - Swedish
    - EU other than Sweden
    - American
    - Non-EU and non-American

Please mark your answer with "X" in the respective row

3. Sample 315

scale		Colour	Aroma	Taste	Flavour intensity	Sweetness	Overall acceptance	Willingness to drink with a meal
9	like extremely							
8	like very much							
7	like moderately							
6	like slightly							
5	neutral							
4	dislike slightly							
3	dislike moderately							
2	dislike very much							
1	dislike extremely							

4. Sample 726

scale		colour	Aroma	Taste	Flavour intensity	Sweetness	Overall acceptance	Willingness to drink with a meal
9	like extremely							
8	like very much							
7	like moderately							
6	like slightly							
5	neutral							
4	dislike slightly							
3	dislike moderately							
2	dislike very much							
1	dislike extremely							

5. Which one is your favourite product?
    - Sample 315
    - Sample 726
6. Comments/Suggestions

Appendix V1. Nutritional composition of breakfast meals for the human study

Meals	Nutritional Value				
	Energy (kcal)	Carbohydrate (g)	Protein (g)	Fat (g)	Fiber (g)
Sandwiches					
3 slices Jättefranska	338.94	59.22	11.214	4.914	3.78
2 packs Bregott	108.48	0.064	0.032	12	0
2,5 slices kokt skinka	30	0.75	7.125	0.413	0
25 g cucumber	13	0.575	0.203	0.013	0
Total	490.42	60.609	18.574	17.34	3.78
Pancake					
3 pannkakor	306	41.4	10.8	11.7	0
60 g Planti greek style gurt	72	2.82	1.98	6	0
25 g strawberry jam	28.75	6.75	0	0	0
100 g orang	25	5.2	0.405	0.1	0.6
Delikatessknäcke (1sk)	30.96	5.85	0.81	0.135	1.53
2 packs Bregott	108.48	0.064	0.032	12	0
Total	571.19	62.084	14.027	29.935	2.13
Oatmeal					
Havregrynsgröt					
50 g havregryn	185	29	6.5	3.5	5
200 ml oat milk	118	13.2	2	6	1.6
1 apple	60	13.225	0	0.0625	2.9
Frukostknäcke (1 piece)	52.65	8.58	1.56	1.17	0.78
2 packs Bregott	108.48	0.064	0.032	12	0
Total	524.13	64.069	10.092	22.73	10.28
Test Drinks					
Placebo	0	0	0	0	0
Control Positive	4		0	0	0
Infused	15.74	3.74	0.09	0.04	0.25

Appendix VII. Glucose iAUC curves

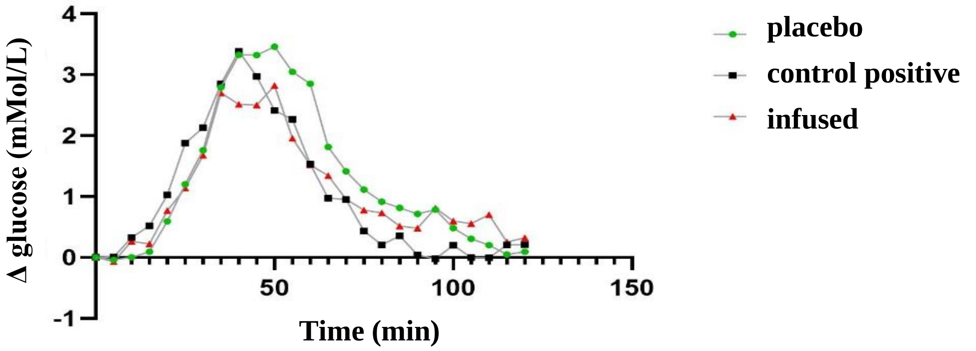


Figure 10. Delta mean values of glucose iAUC with oatmeal breakfast

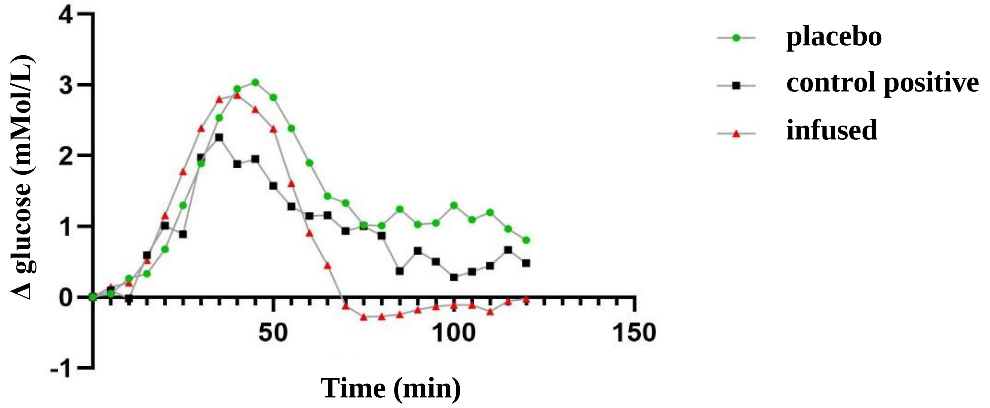


Figure 11. Delta mean values of glucose iAUC with pancake breakfast

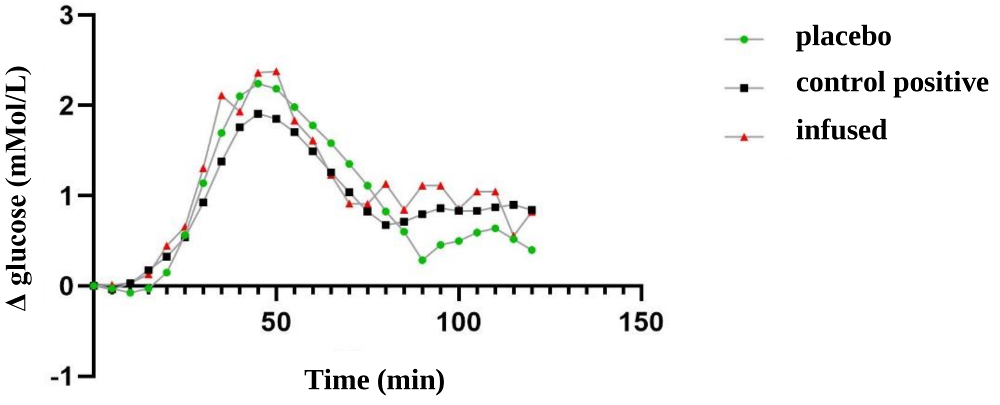


Figure 12. Delta mean values of glucose iAUC with sandwich breakfast