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LATVIA UNIVERSITY OF LIFE SCIENCES AND TECHNOLOGIES

FACULTY OF FOOD TECHNOLOGY

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Doctoral thesis

SAUERKRAUT JUICE FOR NEW PRODUCT DEVELOPMENT
SKĀBĒTU KĀPOSTU SULA JAUNU PRODUKTU IZSTRĀDĒ

for acquiring a Doctoral degree Doctor of science (*Ph.D.)* in Engineering Science and Technologies

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ANNOTATION

Experimental work was carried out in Latvia University of Life Sciences and Technologies, Faculty of Food Technology: scientific laboratory, laboratory of microbiology, biotechnology laboratory, pilot plant for fruit and vegetable processing, laboratory of equipment and processes and chemistry department. Analytical work was also carried out in collaboration with laboratory group J.S. Hamilton. Horizontal spray-drying was carried out in Tecoma Drying Technology SRL, Italy.

The hypothesis of the present work – developed dehydrated and concentrated sauerkraut juice is suitable for application in foods.

The hypothesis was confirmed by the following **thesis**.

1. Physico chemical composition of white cabbage is variety dependant and it affects the composition of sauerkraut
2. Concentration of sauerkraut juice is a suitable technology to obtain a product with high bioactive compound and mineral content.
3. Spray-drying method and carrier agent influence physico chemical composition of dehydrated sauerkraut juice.
4. Dehydrated and concentrated sauerkraut juice affects quality parameters of salad dressings, bread and meat products.

The aim of the present work - to develop dehydrated and concentrated sauerkraut juice and evaluate their quality parameters.

To achieve the aim, following **tasks** have been designated.

1. To analyse the variation in the quality parameters of cabbage and sauerkraut juice depending on variety and harvest year.
2. To evaluate quality parameters of concentrated sauerkraut juice produced by different evaporation technologies.
3. To select appropriate carrier agents for horizontal and vertical spray-drying, evaluating their influence on dehydrated sauerkraut juice quality.
4. To evaluate the effect of dehydrated and concentrated sauerkraut juice on salad dressings, bread and meat quality attributes.

The work is structured into three chapters.

Chapter 1. The theoretical review of the literature describes the characteristics of fresh and fermented cabbage and factors that influence their physicochemical properties. It provides information on the fermentation process. Discusses evaporation methods and encapsulation via spray drying. The review also examines the use of plant-based products in food applications, their sensory characteristics and volatile compounds. Additionally, the review explores *in vitro* digestion and bioaccessibility of sauerkraut juice and its products.

Chapter 2. Description of materials and methods used in this study.

Chapter 3. Summarises the results of research on the physicochemical properties of fresh cabbage and sauerkraut juices. It also investigates the effects of different evaporation technologies on the physicochemical properties of sauerkraut juice, and examines the use of horizontally and vertically spray-dried sauerkraut juice with various carrier agents and concentrations. The study also explores the potential applications of sauerkraut juice products in salad dressings, bread, and meat, and evaluates volatile compounds and sensory characteristics. Additionally, the study analyses the bioaccessibility after digestion *in vitro*.

The thesis is written in English and consists of 137 pages, 31 tables and 40 figures, 194 literature sources and 2 appendixes.

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ANOTĀCIJA

Pētījumi veikti Latvijas Biozinātņu un Tehnoloģiju universitātes, Pārtikas Tehnoloģijas fakultātē: zinātniskajā laboratorijā, augļu un dārzeņu pārstrādes pilotražotnē, procesu un iekārtu laboratorijā, mikrobioloģijas laboratorijā, biotehnoloģijas laboratorijā un Ķīmijas katedrā. Analītiskais darbs tika veikts arī sadarbībā ar laboratoriju J.S. Hamiltons. Kaltēšana ar horizontālās izsmidzināšanas kalti tika veikta Tecoma Drying Technology SRL, Itālijā.

Pētnieciskā hipotēze – izstrādātās dehidrētās un koncentrētās skābētu kāpostu sulas ir piemērotas lietošanai pārtikas produktos.

Promocijas darba hipotēze tika pierādīta ar četrām tēzēm.

1. Kāpostu fizikāli ķīmiskais sastāvs ir atkarīgs no šķirnes un ietekmē skābētu kāpostu sastāvu.
2. Skābētu kāpostu sulas koncentrēšana ir piemērota tehnoloģija bioaktīvo savienojumu saglabāšanai.
3. Izsmidzināšanas kaltēšanas metode un nesējviela ietekmē dehidrētas skābētu kāpostu sulas fizikāli ķīmisko sastāvu.
4. Dehidrēta un koncentrēta skābētu kāpostu sula ietekmē salātu mērču, maizes un gaļas izstrādājumu kvalitātes rādītājus.

Promocijas darba mērķis - izstrādāt dehidrētu un koncentrētu skābētu kāpostu sulu un novērtēt to kvalitātes rādītājus.

Darba mērķu sasniegšanai izvirzīti šādi **pētnieciskie uzdevumi.**

1. Analizēt svaigu un skābētu kāpostu sulas kvalitātes parametru izmaiņas atkarībā no šķirnes un ražas gada.
2. Novērtēt ar dažādām ietvaicēšanas tehnoloģijām iegūtas skābētu kāpostu sulas kvalitātes rādītājus.
3. Izvēlēties piemērotas nesējvielas horizontālajai un vertikālajai izsmidzināšanas kaltei un novērtēt to ietekmi uz dehidrētas skābētu kāpostu sulas kvalitāti.
4. Analizēt dehidrētas un koncentrētas skābētu kāpostu sulas ietekmi uz salātu mērcēm, maizes un gaļas kvalitātes īpašībām.

Darbs strukturēts trīs nodaļās.

1. nodaļa. Teorētiskais literatūras pārskats apraksta svaigu un skābētu kāpostu sulas fizikāli ķīmiskās īpašības un to ietekmējošos faktorus. Tas sniedz informāciju par fermentācijas procesu. Izvērtē koncentrēšanas metodes – ietvaici, iekapsulēšanu ar izsmidzināšanas kaltēm un nesējvielām. Pārskatā izvērtēts augu blakus produktu pielietojums pārtikas produktos. Sniedz informāciju par sensoro novērtēšanu un sagremošanu kuņģa-zarnu trakta simulācijas sistēmā.

2. nodaļa. Pētījumā izmantoto materiālu un metožu apraksts.

3. nodaļa. Pētījums apkopo rezultātus par svaigu un skābētu kāpostu sulas fizikāli ķīmiskajām īpašībām. Tāpat tiek pētīta dažādu ietvaices tehnoloģiju ietekme uz skābētu kāpostu sulas fizikāli ķīmiskajām īpašībām, kā arī tiek izskatīta skābētu kāpostu sulas kaltēšana horizontālā un vertikālā izsmidzināšanas kaltē ar dažādām nesējvielām un to koncentrācijām. Pētījums arī pēta potenciālo skābētu kāpostu sulas produktu izmantošanu salātu mērcēs, maizē un gaļas produktos. Izvērtē gaistošos savienojumus un sensorās īpašības. Turklāt pētījums analizē skābētu kāpostu sulas produktu biopieejamību pēc sagremošanas *in vitro*.

Pētnieciskais darbs ir uzrakstīts angļu valodā uz 125 lapām, ieskaitot 40 attēlus, 31 tabulu un 194 literatūras avotus un divus pielikumus.

Pētījums veikts ar "Eiropas Inovāciju partnerības lauksaimniecības ražīgumam un ilgtspējīgas lauksaimniecības ražīguma un ilgtspējīgas darba grupu projekta īstenošanai" un Zinātnes un projektu attīstības centra / ESF projekti ZPAC / tēma ES32 - "LBTU pāreja uz jauno doktorantūras finansēšanas modeli" ESF projekta Nr. 8.2.2.0/20/I/001, atbalstu.

Latvia University of Life Sciences and Technologies

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APPROBATION OF THE SCIENTIFIC WORK / *ZINĀTNISKĀ DARBA APROBĀCIJA*

The results of this doctoral thesis are published in 5 scientific articles indexed in Scopus or Web of Science databases and presented at 8 international scientific conferences. / *Promocijas darba pētījuma rezultāti publicēti 5 zinātniskajos rakstos, kuri indeksēti Scopus un Web of Science datu bāzēs un prezentēti 8 zinātniskajās konferencēs.*

Publication indexed in databases SCOPUS or Web of Science *\/ Publikācijas, kuras indeksētas datu bāzēs SCOPUS vai Web of Science.*

Scientific journals / *Zinātniskajos izdevumos*:

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Jansone L., Kruma Z., Straumite E. (2023) Evaluation of chemical and sensory characteristics of sauerkraut juice powder and its application in food. *Foods*, 12(1), 19; https://doi.org/10.3390/foods12010019

Jansone L., Kampuse S., Kruma Z., Lidums I. (2022) Quality parameters of horizontally spray-dried fermented cabbage juice. *Proceedings of the Latvian Academy of Sciences.* Section B. Natural, Exact and Applied Sciences, vol. 76(1) (2022), p. 96–102. https://doi.org/10.2478/prolas-2022-0015

Conference proceedings / *Konferenču rakstu krājums*

Jansone L., Kampuse S., Kruma Z., Lidums I. (2021). Evaluation of physical and chemical composition of concentrated fermented cabbage juice. Proceedings of Research for Rural Development 2021: annual 27th International scientific conference proceedings, Jelgava, Latvia, May 12–13, 2021 / Latvia University of Life Sciences and Technologies. Jelgava, Vol.36, P. 84–89. https://doi.org/ 10.22616/rrd.27.2021.012

Jansone L., Kampuse S. (2019). Comparison of chemical composition of fresh and fermented cabbage juice. Proceedings of 13th Baltic conference on food science and technology "Food. Nutrition. Well-Being", Jelgava, Latvia, May 2–3, 2019 / Latvia University of Life Sciences and Technologies. Jelgava: LLU, P. 160–164. https://doi.org/10.22616/FoodBalt.2019.028

Results are presented at 8 international scientific conferences / *Pētījuma rezultāti prezentēti 8 konferencēs.*

1. Jansone L., Kruma Z., Kampuse S. (2022). Dehydrated and concentrated sauerkraut juice in food and cosmetics applications. 15th Baltic conference on food science and technology “Food R&D in the Baltics and Beyond” FoodBalt - 2022, Kaunas, Lithuania, Sept. 26–27, 2022 (oral presentation / mutiska prezentācija).
2. Jansone L., Kampuse S., Kruma Z. (2021). Evaluation of physical and chemical composition of fresh, fermented and dehydrated fermented cabbage juice. 35th EFFoST International Conference “Healthy Individuals, Resilient Communities, and Global Food Security”, Lausanne, Switzerland, Nov. 1–4, 2021 (poster presentation / stenda referāts).
3. Jansone L., Kampuse S., Kruma Z., Līdums I. (2021). Characterization of physical and chemical composition of concentrated fermented cabbage juice. Annual International Scientific Conference “Research for Rural Development”, Jelgava, Latvia, May 12–14, 2022 (oral presentation / mutiska prezentācija).
4. Jansone L., Kampuse S., Kruma Z. (2020). Sauerkraut juice powder chemical and physical properties. 11th International conference Biosystems Engineering: Tartu, Estonia, May 6–8, 2020 (poster presentation / stenda referāts).
5. Jansone L., Kampuse S., Krūma Z., Līdums I. (2020). Characterization of the quality parameters of dehydrated fermented cabbage juice. 3rd International Conference “Nutrition and Health”, Riga, Latvia, Dec. 9–11, 2020 (oral presentation / mutiska prezentācija).
6. Jansone L., Krūma Z. (2020). Innovations in the processing of sauerkraut juice. European Green Course for Bioeconomic Development, Jelgava, Latvia, Dec. 17, 2020, (oral presentation / mutiska prezentācija).
7. Jansone L., Kampuse S., Krūma Z. (2020). Effect of vacuum evaporation on chemical composition and physical parameters of fermented cabbage juice. 4th International Food, Nutrition and Bioprocess Technology conference; Virtual, Oct. 17, 2020 (oral presentation / mutiska prezentācija).
8. Jansone L., Kampuse S. (2019). Comparison of chemical composition of fresh and fermented cabbage juice. FoodBalt 2019: 13th Baltic conference on food science and technology “Food. Nutrition. Well-Being”, Jelgava, May 2–3, 2019 (oral presentation / mutiska prezentācija).

CONTENT/ *SATURS*

List of inserted tables in doctoral thesis / *Promocijas darbā ievietoto tabulu saraksts*

Continuation of the list of inserted tables /
Darbā ietverto tabulu saraksta turpinājums

List of inserted figures in doctoral thesis / *Promocijas darbā ievietoto attēlu saraksts*

Continuation of the list of inserted figures / *Darbā ietverto attēlu saraksta turpinājums*

Continuation of the list of inserted figures / *Darbā ietverto attēlu saraksta turpinājums*

Explanation of designations and abbreviations used / *Izmantoto saīsinājumu un apzīmējumu skaidrojums*

$ABTS^+$	2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) / *2,2'-azino-bis (3-etilbenztiazolina-6-sulfonskābe)*
CE	Catechin equivalent / *katehīna ekvivalents*
CFU / *KVV*	Colony forming units, g^{-1} / *koloniju veidojošās vienības, g^{-1}*
CSJ	Concentrated sauerkraut juice / *koncentrēta skābētu kāpostu sula*
DE	Dextrose equivalent / *dekstrozes ekvivalents*
DPPH•	2,2-diphenyl-1-picrylhydrazyl / *2,2-difenil-1-pikrilhidrazils*
DSJ	Dehydrated sauerkraut juice / *dehidrēta skābētu kāpostu sula*
DW	Dry weight / *sausna*
etc	*et cetera*, further, so on and so forth / *tā tālāk*
eV	Electronvolt / *elektronvolts*
FF	Falling film evaporator / *krītošās plēves ietvaice*
FW	Fresh weight / *svaigā svarā*
GAE	Gallic acid equivalent / *galluskābes ekvivalents*
GLS	Glucosinolates / *glikozinolāti*
g 100 g^{-1}	Gram per 100 grams / *grami 100 gramos*
ISO	International Organization for Standardization / *Starptautiskā Standartizācijas organizācija*
LAB	Lactic acid bacteria / *pienskābes baktērijas*
mbar	Millibar / *milibārs*
MD	Maltodextrin / *maltodekstrīns*
mL	Millilitres / *mililitri*
NAD; NADH	Nicotinamide adenine dinucleotide / *nikotīnamīda adenīndinukleotīds*
OD	Open kettle evaporation in “Dimdiņi” Ltd / *atvērta tipa katla ietvaice SIA “Dimdiņi”*
PCA	Plate count agar / *kopējo mikroorganismu barojošais agars*
pH	Negative logarithm of hydrogen ion concentration / *negatīvais logaritms no ūdeņraža jonu koncentrācijas*
PJ	Pasteurized sauerkraut juice / *pasterizēta skābētu kāpostu sula*
Rpm	Revolutions per minute / *apgriezieni minūtē*
SS	Starch solution / *cietes šķīdums*
TE	Trolox equivalent / *troloksa ekvivalents*
Tg	Glass transition temperature / *stiklošanās temperatūra*
TSS	Soluble solids / *šķīstošā sausna*
US	Ultrasound / *ultraskaņa*

INTRODUCTION

White cabbage (*Brassica oleracea* L. var. capitata) has long been one of the most accessible and cultivated vegetables in Latvia and worldwide. They are widely consumed both fresh and in cooked meals (Martínez et al., 2020). However, one of the most common products in white cabbage processing is sauerkraut. In the process of fermentation, lactic acid is formed under the influence of lactic acid bacteria. The chemical composition of cabbage changes, resulting in sauerkraut that is rich in nutrients - vitamins, minerals, organic acids and fibre, modulating health properties (Tlais et al., 2022). During the production of sauerkraut, juice is released almost immediately after the addition of salt, and can sum up to 30% till the end of the process. However, it is also a valuable source of various bioactive compounds and functional metabolites. In the process of packaging and retail, a part of this valuable juice remains unused and is considered as a waste. The research into development of new technologies and the value-added sauerkraut juice would contribute to sustainable, residue - free technology in processing as well as create high value-added products.

The **hypothesis** of the present work – developed dehydrated and concentrated sauerkraut juice is suitable for application in foods.

The aim of the present work - to develop dehydrated and concentrated sauerkraut juice and evaluate their quality parameters.

To achieve the aim, following **tasks** have been designated.

1. To analyse the variation in the quality parameters of cabbage and sauerkraut juice depending on variety and harvest year.
2. To evaluate quality parameters of concentrated sauerkraut juice produced by different evaporation technologies.
3. To select appropriate carrier agents for horizontal and vertical spray-drying, evaluating their influence on dehydrated sauerkraut juice quality.
4. To evaluate the effect of dehydrated and concentrated sauerkraut juice on salad dressings, bread and meat quality atributes.

Novelty and scientific significance.

1. For the first time detailed evaluation of sauerkraut juice quality has been conducted and it has been used in the creation of new products.
2. A technology has been developed for obtaining innovative ingredients in the food industry - dehydrated and concentrated sauerkraut juice.

Economic significance.

1. Technological solutions for development of sauerkraut juice products would create a sustainable use of agricultural resources, reducing waste by exploiting by-products.
2. The products developed in the study would allow manufacturers to expand the product range with new, innovative solutions.

1. REVIEW OF LITERATURE / *LITERATŪRAS APSKATS*

1.1. The characterisation of white cabbage / *Galviņkāpostu raksturojums*

The history of *Brassica oleracea* subsp. *oleracea* reaches as far as 3000 BC (Roland et al., 2018.) . It has been consumed by various groups of society: from Caesar, Aristotle to seamen and slaves (Šamec et al., 2017), mainly because of its health-promoting benefits - anti-cancerogenic, anti-inflammatory and anti-oxidative potential (Kusznierewicz, Bartoszek, et al., 2008; Kusznierewicz et al., 2010; Moreb et al., 2020) to treat gastrointestinal issues, inflammation, gout, diarrhoea and detoxifying the body.

The taxonomy of white cabbage is as follows: family *Brassicaceae*, genus *Brassica*, species *oleracea*, variety *capitata*. It is a multi-layered-green-leaf head that grows on a stem. There is a great variation among the cultivars ranging in size (0.5 – 4kg), shape (round to conical), colour (green to pale green to almost white), texture (softer to harder) (Singh et al., 2006).

Researchers that have worked on investigating cabbage (*Brassica oleracea* L. var. *capitata*) start their research stating that cabbage is "one of the most important vegetables grown worldwide" (Balkaya et al., 2005; Citak & Sonmez, 2010; Hallmann et al., 2017; Šamec et al., 2017; Moreb et al., 2020; Wermter et al., 2020; Kumar et al., 2022) due to their availability, cheapness and consumer preferences (Kusznierewicz, Bartoszek, et al., 2008b).

Although *Brassicas* are cool weather crops, they are known and grown worldwide in various climatic conditions. In the year 2019 *Brassicas* were grown in 2.45 million hectares around the world with a production crop being more than 70 million tonnes (average yield almost 3 t ha^{-1}). Average consumption in Poland and Sweden is 6.3 kg per person, annually (Moreb et al., 2020). Most crops are harvested in China, India and Russia (*FAOSTAT*[1]). In Latvia in year 2021 cabbage was grown in 1.4 thousand hectares with a crop of 41 900 tons[2] (Table 1.1.).

Table 1.1 / *1.1. tabula*

Cabbage sown area, crop and average yield in Latvia in 2018 – 2021 /
Kāpostu sējumu platība, kopraža un vidējā ražība Latvijā no 2018 – 2021 gadam

Parameter / *Rādītājs*	**Year /** *Gads*			
	2018	**2019**	**2020**	**2021**
Sown area, thousand ha / *Sējumu platība tūkst.ha*	1.8	1.9	1.6	1.4
Crop, thousand tons / *Kopraža tūkst. tonnu*	46.8	53.2	43.0	41.9
Average yield, cnt ha^{-1} / *Vidējā ražība cnt* ha^{-1}	254.0	286.0	272.0	296.0

Despite their presumably easy cultivation, there are many factors that influence plant's metabolism, thus chemical composition and taste (Björkman et al., 2011). The factors influencing cabbage metabolism are compiled in Fig 1.1.

[1] FAOSTAT, Production/Yield quantities of cabbages in the World [online] [viewed on 07. March 2023]. Retrieved from https://www.fao.org/faostat/#dataQC

[2] Lauksaimniecības kultūraugu sējumu platība, kopraža un vidējā ražība - kultūraugi, rādītājs un laika periods [online] [viewed on 07. March 2023]. Retrieved from https://data.stat.gov.lv

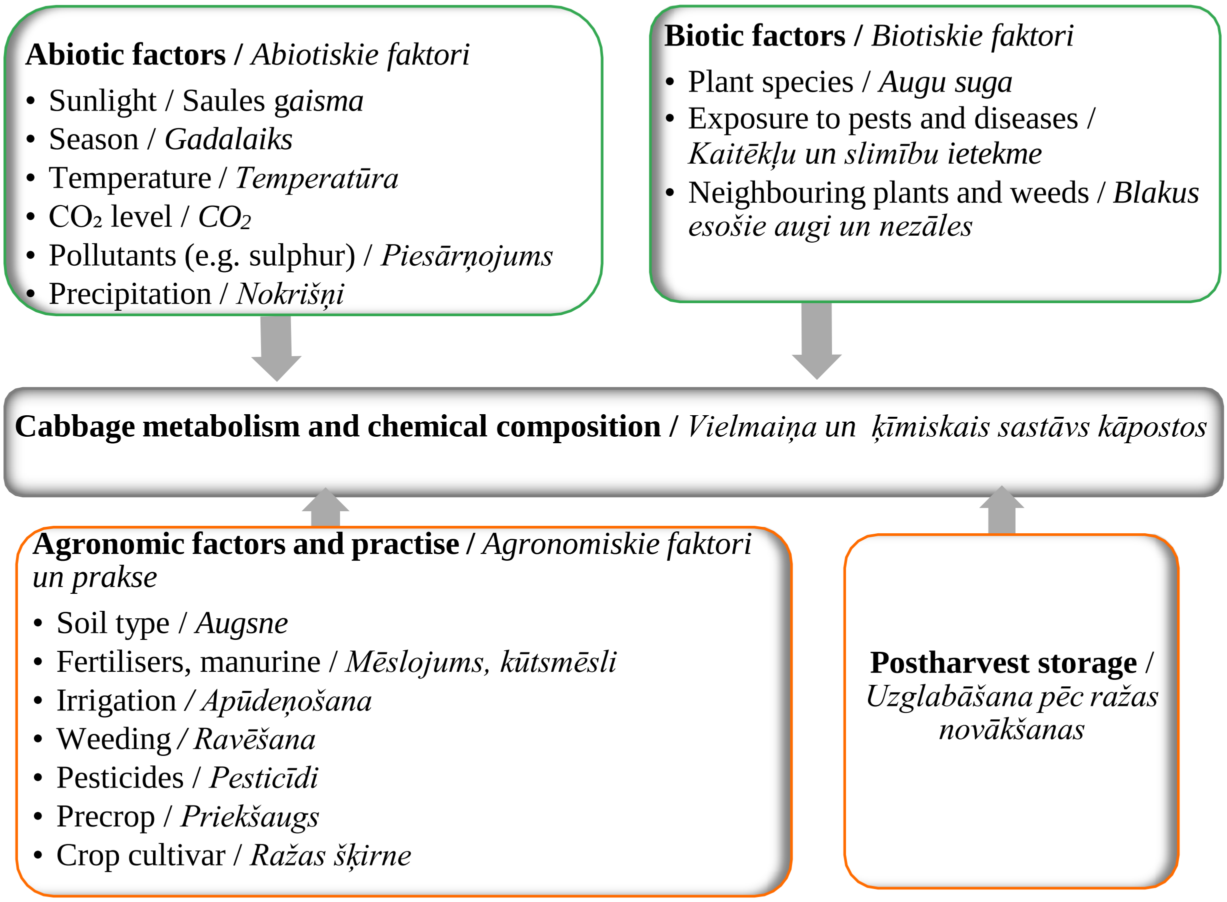

Fig. 1.1. **Factors influencing cabbage metabolism and chemical composition /** *1.1. att. Kāpostu vielmaiņu un ķīmisko sastāvu ietekmējošie faktori* (Björkman et al., 2011; Jabeen & Kosson et al., 2017; Šamec et al., 2017; Kovalikova et al., 2019; Chadha, 2021)

Various scientists (Aires et al., 2011; Šamec et al., 2017) are explaining the climate impact on chemical composition of *Brassica* vegetables. Abiotic factors refer to non-living factors that can influence the growth and development of cabbage. Examples of abiotic factors include temperature, water availability, soil type, and nutrient availability. Biotic factors refer to living organisms that can influence the growth and development of cabbage. Examples of biotic factors include pests, diseases, and microorganisms (Kovalikova et al., 2019). Agronomic factors are related to the management practices that are used to grow cabbage. These include irrigation, fertilisation, and crop rotation. For example, proper irrigation can help ensure that the cabbage plants have adequate water to grow and develop, which can help increase their overall nutrient content (Jabeen & Chadha, 2021). Similarly, fertilisation practices can influence the levels of nitrogen, phosphorus, and potassium in cabbage. Crop rotation can also influence the nutrient content of cabbage by reducing the build-up of soil-borne diseases and pests. Kosson and colleagues (2017) have determined the effect of fertilisers on the chemical composition of white cabbage and have detected differences in ascorbic acid, fructose and glucose contents (Kosson et al., 2017). Even though organic fertilising with compost and manure contains less available nitrogen and plants grow more slowly, the cabbage contains more bioactive compounds than conventional ones (Hallmann et al., 2017a). Nitrogen, phosphorus and potassium are important for formation and the quality of the cabbage head (Citak & Sonmez, 2010). Also, as investigated by Kusnierewicz et.al. (2008), the water stress can be related to increased synthesis of sugars and amino acids which partake in biosynthesis of glucosinolates (GLS) and thus higher content of GLS may contribute to higher level of antioxidative potential (Kusznierewicz, Śmiechowska, et al., 2008). As well as the time of harvest influence the level of bioactive compounds – the autumn crop has been exposed to sunlight longer thus affecting synthesis of phytochemicals (Kusznierewicz, Bartoszek, et al., 2008b; Moreb et al., 2020).

Though all of the above-mentioned factors influence physicochemical composition of the cabbage, the exact amounts of specific compounds cannot be definitively stated. The results have been determined in different times, regions, crops etc., so there are possibilities in variation, as shown in Table 1.2.

Table 1.2. / *1.2. tabula*

Physicochemical parameters of fresh cabbage[3] / *Svaigu kāpostu fizikāli ķīmiskie rādītāji* (Kusznierewicz, et al., 2008; Kusznierewicz et al., 2010; Moreb et al., 2020)

Parameters / *Parametri*, **100 g^{-1}**	**White cabbage** / *Baltie galviņkāposti* (*Brassica oleracea*)
pH	5.9 – 6.3
Soluble solids / *Šķīstošā sausna*, °Brix	5.7 – 8.5
Moisture / *Mitrum*s, %	92 – 94
Total phenols / *Kopējie fenoli*, mg GAE, FW	40.2 – 59.5
Vitamin C / *C vitamīns*, mg	13.5 – 51.7
Vitamin A / *A vitamīns*, µg	31 – 98
Vitamin K / *K vitamīns*, µg	74 – 76
Energy value / *Enerģētiskā vērtība*, kcal	24 – 36
Glucose / *Glikoze*, g	1.7 – 3.5
Fructose / *Fruktoze*, g	1.4 – 2.2
Dietary fibre / *Šķiedrvielas*, g	2.5 – 3.4
Protein / *Olbaltumvielas*, g	0.9 – 2.4
Fat / *Tauki*, g	0.1 – 0.2
Ash / *Pelnvielas*, g	0.53 – 0.70
Magnesium / *Magnijs*, mg	12 – 13
Potassium / *Kālijs*, mg	170 – 304
Iron / *Dzelzs*, mg	0.4 – 0.5
Calcium / *Kalcijs*, mg	40 – 46

Fresh cabbage has a moisture content of approximately 93%, low in calories, protein, and fat content. There is a moderate amount of carbohydrates in fresh cabbage, including fructose, glucose and traces of sucrose, soluble and insoluble fibre (Rodriguez-Amaya, 2015). As Moreb and colleagues (2020) have reviewed, cruciferous vegetables contain all essential amino acids - valine, lysine, isoleucine, leucine, methionine, tryptophan, phenylalanine, threonine and histidine.

There is a considerable variation in vitamin C in fresh cabbage, from 13.5 to 51.7 mg 100 g^{-1} (Šamec et al., 2017; Moreb et al., 2020) and vitamin A 31 to 98 µg 100 g^{-1}, vitamin K 76 µg 100 g^{-1}. It is also a valuable source of minerals such as calcium, potassium, magnesium, and trace elements – manganese (Mn), iron (Fe), zinc (Zn), copper (Cu), selenium (Se) (Harbaum-Piayda et al., 2016; Moreb et al., 2020). White cabbage also contains phenol compounds including polyphenols and flavonoids (Kusznierewicz, Bartoszek, et al., 2008b).

White cabbage and *Brassicas* vegetables in general are the most abundant plants with glucosinolates – water soluble, sulphur containing bioactive substances identified with pungent mustard aroma (Avato & Argentieri, 2015; Šamec et al., 2017; Kumar et al., 2022). Glucosinolates are released, when the cabbage is treated mechanically, by cutting, chopping or chewing and the cell walls are broken, resulting in GLS hydrolyses by the enzyme myrosinase

[3] FoodData Central, cabbage raw [online] [viewed on 21. January 2023]. Retrieved from https://fdc.nal.usda.gov/fdc-app.html#/food-details/169975/nutrients

(EC 3.2.3.1[4]). The bioactive metabolites of this hydrolysis are isothiocyanates, thiocyanates, nitriles, epithionitriles or oxazolidine-2-thiones (Ghawi et al., 2012; Wermter et al., 2020) derived from predominant GLS, sinigrin and glucobrassicin (Ciska et al., 2021). Their concentration in white cabbage is particularly high in the inner leaves (Zhao et al., 2020). The chemical structure of GLS consists of a sulfonated oxime group linked to glucose and an alkyl, aralkyl or indolyl side chain (the side chain R varies) (Prieto et al., 2019). The high amount of glucosinolates cited in literature is due to more than 200 side – chains (R) identified (Clarke, 2010; Prieto et al., 2019). The basic chemical structure and hydrolysis of glucosinolate is shown in Fig.1.2.

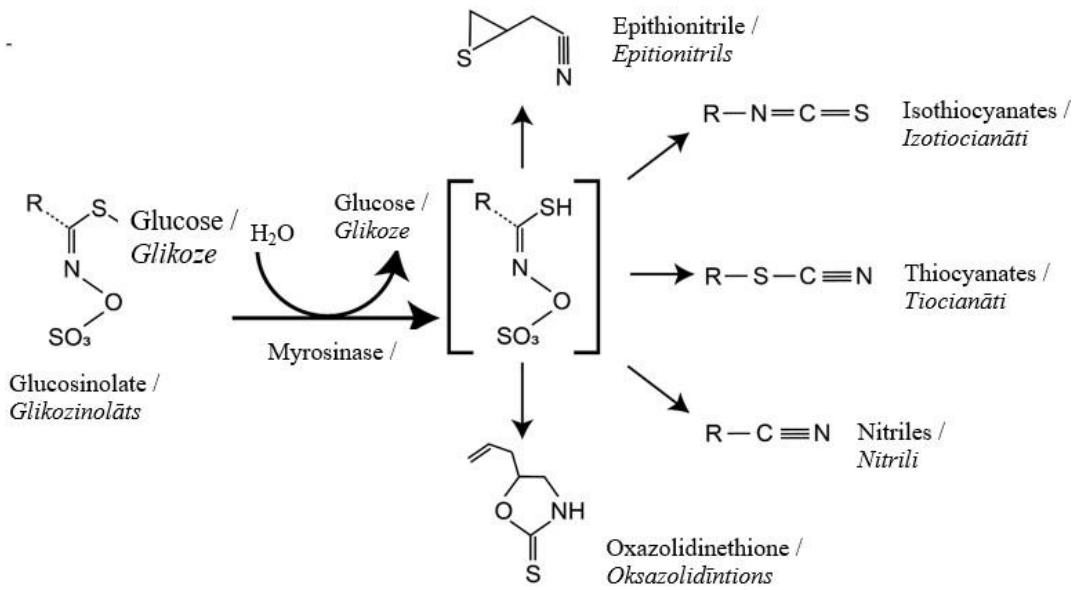

Fig.1.2. **Glucosinolate chemical structure and hydrolyses /**
1.2. att. Glikozinolāta ķīmiskā struktūra un hidrolīze (Clarke 2010; Prieto et al.,2019)

Kusznierewicz and colleagues (2008) have concluded that high content of GLS in cabbage can also go along with higher levels of antioxidants. In the review by Dr D.B. Clarke (2010) epidemiological evidence indicates that glucosinolates and their metabolic products of *Brassicas* vegetables have chemoprotective effects on tumours.

Chemical composition and bioactive components may even differ in plants of the same cultivar, grown under the same conditions, or even in just one individual cabbage head. Sugars and glucosinolates increase closer to the core however antioxidant capacity is higher closer to the outer leaves (Aires et al., 2011; Kosson et al., 2017; Zhao et al., 2020).

Previous studies of factors influencing chemical composition of white cabbage are done in different conditions, years, countries, therefore it may be difficult to come to one exclusive conclusion. As well as all the mentioned factors influence the chemical and physical composition of fermented cabbage, known as sauerkraut.

1.2. Characterization of the fermentation process and sauerkraut / *Fermentācijas procesa un skābētu kāpostu raksturojums*

Derived from Latin "fermentum", fermentation means "natural decomposition process which involves chemical transformation of complex organic substances into simpler compounds by the action of intrinsic organic catalysts generated by microorganisms" (Steinkraus, 1983; Xiang et al., 2019). The outcome of these microbiological changes is

[4] EC – Enzyme Commission number, ENZYME - Enzyme nomenclature database [online] [viewed on 07. March 2023]. Retrieved from https://enzyme.expasy.org/EC/3.2.1.147

improved nutritional value, sensory quality with unique textures and flavours, and health promoting properties with increased digestibility of fermented products (Xiang et al., 2019; Rastogi et al., 2022).

Fermentation, as a preservation method, has been used in human history since ancient times (Gruszecki et al., 2022). Food groups that are being fermented world wide include dairy, cereal, fish, meat, tea, with more than 3500 products. Also, a variety of vegetables such as fermented soy beans – Japanese 'miso', 'nato', Indonesian 'tempeh', cucumbers, mushrooms, olives, turnips, eggplants, garlic etc are being fermented (Rastogi et al., 2022). But cabbage is the most commonly fermented vegetable - Chinese Pao Cai, Korean 'kimchi' (Xiang et al., 2019; Torres et al., 2020) as well as sauerkraut - one of the most popular condiment in Central and Eastern Europe and also in the United States and Asia (Özer & Kalkan Yıldırım, 2019; Di Cagno et al., 2021).

Fermented products are a healthy condiment and are regaining popularity nowadays due to increased nutritional and functional properties, extended shelf-life and sensory qualities (Özer & Kalkan Yıldırım, 2019; Di Cagno et al., 2021). Also, the rising demand in current circumstances, for efficient utilisation of agro wastes (Xiang et al., 2019).

The term 'sauerkraut' originates from a German language, meaning 'sour cabbage'. Traditional process to produce sauerkraut is via spontaneous fermentation that relies on indigenous lactic acid bacteria (LAB) (Beganović et al., 2014), naturally occurring on cabbage leaves (Peñas et al., 2010; Satora et al., 2021). Spontaneous fermentation is also influenced by many factors – salt concentration and temperature being the most consequential, but also vegetable freshness and natural microflora, fermentation time and salt (NaCl) type affect the result of sauerkraut (Özer & Kalkan Yıldırım, 2019).

The process of fermentation is divided into several steps. The outer leaves of the fresh cabbage heads are trimmed off and the core is removed. The cleaned head is then shredded into 0.7 – 2.5 mm strips and mixed with 1 - 2% salt. The amount of NaCl added differs by cultural features and market preference. Chinese sauerkraut, the records of which reaches 3000 years ago from the Zhou Dynasty, considers a low salt concentration of 2 – 10% (Xiong et al., 2016) via fermentation in brine. The Netherlands markets sauerkraut with 5% NaCl (Wolkers-Rooijackers et al., 2013). The taste preferences of sauerkraut in Latvia is with 1.5 – 1.8% salt concentration, and addition of caraway seeds. It is common to add shredded carrots and sometimes cranberries or even pieces of apple in the fermentation process. Though research states that 1 – 2% of salt concentration is optimum to inhibit undesirable microflora yet keeping LAB (lactic acid bacteria) active (Man, 2007; Fan et al., 2015). Though, a study states that 0.5% has a better effect on ascorbigen activation, which is precursor of glucobrassicin (Peñas et al., 2010; Xiong et al., 2016). The addition of salt withdraws juice in the plasmolysis from the shredded cabbage tissues thus creating a satisfactory environment for LAB development (Fan et al., 2015). Salt ions acts as enzyme activators or deactivators, depending upon its concentration (Zhang et al., 2022).

The expelled cabbage juice is rich in fermentable sugars and nutrients that are valuable for LAB growth and activity (Fan et al., 2015). The outcome of the glucose catabolism results in pyruvate and source of adenosine triphosphate energy (ATP). One glucose molecule generates two pyruvic acid molecules, two molecules of ATP and two nicotinamide adenine dinucleotide and hydrogen molecules (NADH). In the anaerobic lactic acid fermentation, performed by LAB, pyruvate is transformed to lactic acid and during the process regenerates NAD^+, allowing to make ATP in low oxygen conditions (Di Cagno et al., 2013; Erten et al., 2015; Chaudhry & Varacallo, 2018).

The fermentation of cabbage usually starts with the application of heterofermentative cocci *Leuconostoc mesenteroides* that, under optimal temperature, i.e., 18 – 22 °C for 4 – 7 days, begin to produce lactic acid (Fan et al., 2015). During further fermentation, spoilage microorganisms' inhibition occurs due to the accumulation of lactic acid. Carbon dioxide production favourably affects anaerobiosis, as stated by Xiang (Xiang et al., 2019). It has been reported that *L. mesenteroides* enhances the flavour of sauerkraut (Özer & Kalkan, 2019).

In excess of lactic acid, the catalytic activity of *L. mesenteroides* considerably reduces, eventually leading to its inhibition. From this time more acid tolerant lactobacilli (*Lactobacillus plantarum, Lactobacillus brevis)* and *Pediococus cerevisiae* continue the fermentation process (Xiong et al., 2012).

LAB metabolites change the chemical, biological and sensory properties of fermented products (Xiang et al., 2019) resulting in a completely different product.

Since ancient times, people have believed that sauerkraut is beneficial to their health because of the high amount of nutrients it contains (Gruszecki et al., 2022; Rastogi et al., 2022). Sauerkraut contains phenolic compounds and glucosinolates (Peñas et al., 2017b), organic acids, with lactic acid being predominant, also acetic, citric and malic acids, sugars – glucose, fructose. It is a source of vitamins, especially vitamin C that ranges from 14.7 – 75 mg 100 g^{-1} FW (Martinez-Villaluenga et al., 2009; USDA Nutrient Data Laboratory) and minerals like sodium (661 mg 100 g^{-1}), calcium (30 mg 100 g^{-1}), potassium (170 mg 100 g^{-1}) (Peñas et al., 2017a). But, meanwhile, a formation of biogenic amines, like tyramine and histamine also take place during fermentation, and have a negative effect on human health (Satora et al., 2021).

The taste and flavour of fermented food is the primary factor of sensory qualities and is usually the deciding factor of acceptance by consumers (Major et al., 2022). These characteristics are influenced by variety, amount of salt used in the fermentation, fermentation and storage conditions. Although sauerkraut is sensory complex, its basic sensory qualities are characterised by appearance (colour and gloss), texture (hardiness and crunchiness) (Major et al., 2022). The amount of salt used in the fermentation process has a significant impact on texture and appearance on sauerkraut - crunchiness decreases as the salinity increases (Satora et al., 2021). The aroma of sauerkraut is characterised by strong or weak pungent aroma, off-flavour or typical fermented aroma, vegetable-specific and sulphur notes (Satora et al., 2021). As Martínez-Villaluenga et.al. (2020) have investigated, the distinctive sulphur-like flavour of sauerkraut is a sign of high quality, which is derived from glucosinolates present in fermented cabbage.

A specific sauerkraut flavour forms during fermentation and is affected by LAB strains and their potential to metabolise certain lipids, amino acids, glucosinolates, etc. (Wieczorek & Drabińska, 2022). Alcohols and sulphur compounds, the hydrolysis products of glucosinolates - isothiocyanates, thiocyanates and nitriles, and their metabolites are the most numerous groups of aromatic compounds (Major et al., 2022), that form the specific sauerkraut aroma, as well as esters, aldehydes, ketones and many others (Major et al., 2022). Isothiocyanates form pungent aroma and are also beneficial from a nutritional perspective, exhibiting anticancer properties and chronic disease prevention (Peñas et al., 2012; Palliyaguru et al., 2018.; Ciska et al., 2021).

Penas has investigated that fermentation of white cabbage caused five different volatile compound formation, in degradation of GLS – iberin, iberin nitrile, allyl cyanide and allyl isothiocyanate, that were not present in raw cabbage. Allyl isothiocyanate, is an abundant volatile in sauerkraut, derived from sinigrin, with a pungent taste of mustard, horseradish and wasabi.

There were more than 60 volatile compounds identified in the sauerkraut, obtained from different cabbage varieties, (Satora et al., 2021) that distinguish specific sauerkraut organoleptic attributes. Just like chemical and physical parameters are affected by different factors, so the composition of volatile compounds is influenced by the choice of variety, fermentation conditions, such as temperature and NaCl concentration, as well as duration and temperature of storage etc ((Peñas et al., 2012; Satora et al., 2021; Major et al., 2022). Also, commercially available sauerkrauts had significantly different and decreased amount of volatile compounds (Major et al., 2022).

Volatile compounds are organic compounds that have higher vapour pressure and emit as gaseous from solids or liquids at ambient temperature. As all organic compounds, they contain carbon and also elements like hydrogen, oxygen, sulphur, bromine and some others (Anand et al., 2014). Volatile organic compounds are alcohols, ethers, esters, aldehydes, aromatic hydrocarbons etc.

Early findings (Hang et al., 1972) agree with the information given from the sauerkraut producers today – there are ~ 30% of sauerkraut juice left as a by-product from the production process. There are quite a few studies on sauerkraut – chemical composition, bioactive compounds, sensory quality etc., yet little or no studies are done on sauerkraut juice that is released in the fermentation process, still rich in valuable and beneficial compounds (Jansone & Kampuse, 2019).

Therefore, the research on sustainable solutions for preservation and utilisation of the sauerkraut juice must be done. To concentrate the juice via evaporation or dehydrate via spray – drying may be a solution.

1.3. Description of evaporation and dehydration methods / *Ietvaices un kaltēšanas metodes apraksts*

Evaporation process prolongs the shelf life of the liquid by reducing water activity thus increasing microbiological stability of the product (Sabanci & Icier, 2017). There are economical advantages as well, like packaging, storage and transportation (Salehi, 2020), since the volume of the liquid is significantly reduced. Evaporation changes compositional features, like consistency, by concentration of soluble solids, and enchanted flavour (Adnan et al., 2018). Thus, the more juice is concentrated the less it resembles the original product (Adnan et al., 2018).

Fruit juices are the major category for concentration due to their seasonality, vulnerability and short shelf-life and orange and apple juices comprise the largest segment (Adnan et al., 2018). The level of total soluble solids of most fruit juice concentrates is between 20 – 30 Brix° (Adnan et al., 2018). FAO[5] has developed a standard that defines that a Brix level of a fruit juice concentrate is at least 50% higher than a reconstituted juice made from the same fruit. There are scarce studies on concentrated vegetable juices, since they store well, though tomato juice is being concentrated to increase lycopene content (Alaei et al., 2022), also influence of beetroot juice concentration on betalain content (Bazaria & Kumar, 2020). Though there are commercial companies offering carrot and beetroot juice concentrate with 60 Brix°.

To the best of our knowledge, there are no studies on concentration of sauerkraut juice.

For industry requirements there are various techniques and methods to achieve a concentrated product via evaporation with desirable characteristics and outcome (Adnan et al., 2018; Subhabrata & Gargi, 2020).

Evaporator types can be classified as follows (Subhabrata & Gargi, 2020):

- by heating method – direct or indirect; type of heat transfer surface – plate or tubular;
- by mode of operation – batch or continuous.

The continuous flow apparatus has a diverse variation by the nature of liquid circulation over heating surface (Subhabrata & Gargi, 2020):

- natural circulation, usually in a short tube, horizontal, vertical or basket type;
- forced circulation – boiling in a tube or submerged type;
- film type, also divided by the movement of the film, usually in a long tube:
  - climbing film
  - falling film
  - climbing-falling film
  - wiped film.

[5] FAO General standard for fruit juices and nectars (codex stan 247-2005) [online] [viewed on 23. March 2023]. Retrieved from https://www.fao.org/fao-who-codexalimentariusproxy

In a falling film evaporator, the liquid/juice flows by gravity as thin film on the inside of heated vertical tubes and the steam on the outside (Subhabrata & Gargi, 2020). This liquid forms a thin film only on the heat transfer surface and does not occupy the entire tube cross-section, resulting in a short contact time with the heating surface[6]. It should be distributed evenly around the tubes not to form spots and clots. Falling film evaporators are suitable for heat-sensitive liquids, because this process ensures low, below 90°C, temperature regimes and residence time (Adnan et al., 2018; Gong et al., 2020). The schematic operation of a falling film evaporator is depicted in Fig 1.3.

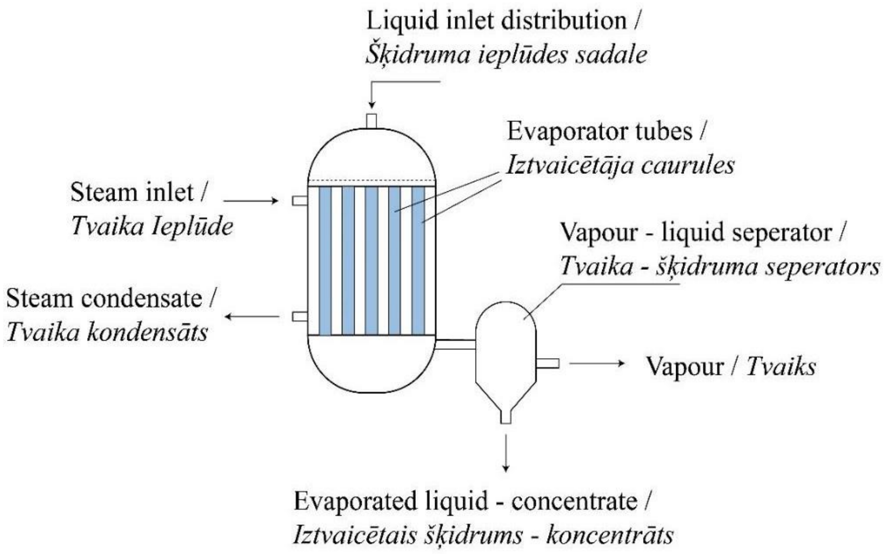

Fig. 1.3**. A schematic description of a falling film evaporator** /
1.3. att. Krītošās plēves ietvaices iekārtas shematisks attēlojums (Subhabrata R; Gargi, 2020)

In a rotary vacuum evaporation, the evaporation chamber rotates in a water bath under a vacuum pressure that is applied during the process. The evaporation process is influenced by reduced pressure, speed of revolutions, and a temperature below 50°C, that allow to preserve biologically active compounds, like total phenols, organic acids etc. (Bazaria & Kumar, n.d.; Editors et al., 2020; Elik et al., n.d.)

Dehydration by spray-drying – an atomizer device converts a liquid sample into small droplets, which, being in contact with hot air, lose their moisture and form dry solid particles (Barbosa & Teixeira, 2017a). It is the most common and oldest technology used for microencapsulation – in order to protect core material (the material inside the microcapsule) a protective coating (also known as wall material, carrier agents, shell, coating) is used (Gharsallaoui et al. 2007) and microcapsules are formed - a small sphere with a uniform wall around it.

The first patent documented on the use of spray-drying dates back to 1872 (Barbosa & Teixeira, 2017a) and nowadays is the most economic drying technique used by the food industry for the production of food powders (Shishir & Chen, 2017).

Spray-drying comprises three steps: 1) homogenization of feed liquid by an atomizer; 2) drying of liquid droplets by a hot gas carrier to achieve the evaporation; 3) and collection of dry particles in a cyclone (Ozkan et al., 2019). The spray-drying schematic process is shown in Fig. 1.4.

[6] GEA – Falling film evaporators [online] [viewed on 21. January 2023]. Retrieved from https://www.gea.com/en/products/evaporators-crystallizers/evaporator-plants/falling-film-evaporator.jsp

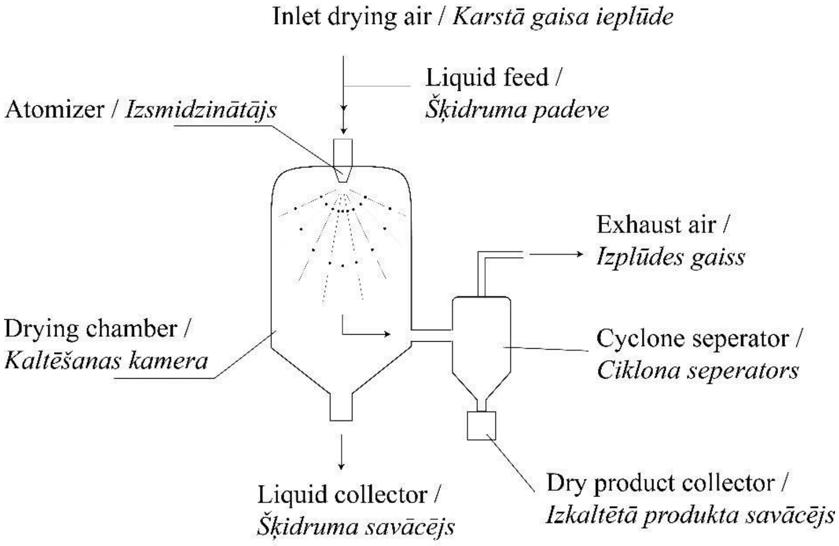

Fig. 1.4**. Schematic description of vertical spray-drying process /**
1.4. att. Vertikālās izsmidzināšanas kaltes shematisks attēlojums (Shishir & Chen, 2017)

In short, the process is compiled in a spray tower, usually a cylindrical apparatus and a core material is sprayed by a nozzle from the top by an atomizing device. Atomization is a very important stage in the drying process. The principal function of an atomizer is to create a maximum surface area of the core feed to optimise the heat-mass transfer for effective and efficient drying (Gharsallaoui et al. 2007; Shishir & Chen, 2017). The higher the energy delivered, the smaller is the size of droplets achieved. The physical properties of spray-dried products are influenced by atomization pressure (Shishir & Chen, 2017a). In this process, the sprayed particles are exposed to hot air and the drying process or evaporation starts. The moisture from the droplets evaporates by the means of hot air and dry particles are formed (Barbosa & Teixeira, 2017). The air (gas) inlet is located on the side and creates a swirl flow (Bück, 2018). The dry particles are then separated from the hot air flow in the cyclone and collected in a collecting unit (Shishir & Chen, 2017). The characteristics of the final product – dried particles – are influenced by all the spray-drying process factors – hot air temperature and flow rate, feed flow rate, pressure and nozzle configuration (diameter), type and concentration of the carrier agent (Ozkan et al., 2019).

The core materials to be spray-dried can be classified in two main groups: sticky and non-sticky materials (Krishnaiah et al., 2014). There are no difficulties met when spray-drying non-sticky products. On the contrary, the sticky ones are challenging. Mostly those are fruit and vegetable juices with low pH. Their behaviour manifests as sticking to the dryer's walls, retaining syrup-like consistency or forming unwanted agglomerates. It is due to the presence of sugars and organic acid rich compounds, like sucrose, fructose, glucose, citric acid, malic acid, which have low molecular weight compounds with low glass transition temperatures (Tg) (Shishir & Chen, 2017). "Glass transition temperature is the temperature range where polymer substrate changes from a rigid glassy material to a soft (not melted) material, and is usually measured in terms of the stiffness or modulus" (Becker & Locascio, 2002). However, this issue can be solved by homogenising the core and the carrier agent. The carrier agent usually has a high molecular weight and thus higher glass transition temperature. The carrier agent forms an external layer on the drying particle and changes the stickiness of its surface (Barbosa & Teixeira, 2017) as shown in Fig. 1.5.

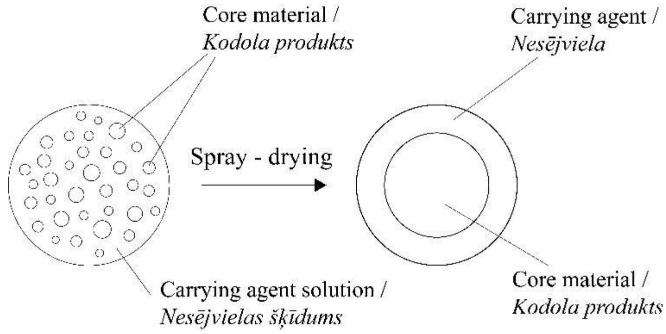

Fig. 1.5. **Schematic description on encapsulating /**
1.5. att. Iekapsulēšanas shematisks attēlojums

There is a variety of carrier agents used in spray drying: 1) starch and its derivatives, like maltodextrins and dextrins; 2) gums, like gum arabic and karaya gum; 3) cellulose and 4) proteins like soy and whey proteins and sodium caseinate (Đordević et al., 2016).

The choice of carrier agent is crucial and depends on the core material properties and the desired result of dehydrant.

Sauerkraut juice can be considered as a complex multicomponent system with sugars and organic acids.

Spray-drying proved to be efficient technique to encapsulate blueberry polyphenols in protein as a core material (Correia et al., 2017), however Araujo-Diaz et.al. (2017) observed that spray-drying blueberry juice with inulin presented the lowest content of antioxidants, compared to the sample spray-dried with maltodextrin. However, spray-drying fermented beetroot juice with maltodextrin did not protect betacyanins and betaxanthins.

Maltodextrin is the most commonly used carrier due to its low cost and protection of bioactive compounds of the core material from the impact of high temperature during spray-drying (Araujo-Díaz et al., 2017; A. M. Ribeiro et al., 2020). It consists of D – glucose units, that are primarily linked with α (1→4) glycosidic bonds and is with variable dextrose equivalent from 3 to 20 (Teo et al., 2021). Gums are most suitable for encapsulating vitamins (Ribeiro et al., 2020). Alginates are mostly suitable for drug encapsulation (Wardhani et al., 2021). Proteins are amphiphilic and are suitable for hydrophobic core material encapsulation (Ribeiro et al., 2020). According to Ballesteros et.al. (2017), maltodextrin is pre-eminent to encapsulate phenolic compounds, flavonoids and antioxidant activity in spent coffee grounds against gum Arabic.

The use of a carrier agent offers two benefits to the spray - drying of sticky core materials – it facilitates the process and serves as a coating for the dried particles, protecting them from chemical degradation and allowing for better control of their reaction to environmental changes such as temperature, pH, light and humidity (Đordević et al., 2016). Additionally, the carrier agent can protect heat-sensitive compounds during the drying process and may preserve antioxidant properties and nutritional value (Barbosa & Teixeira, 2017b). Different types of carrier agents may be combined to achieve the desired encapsulation outcome.

Therefore, it is very essential to choose the right carrier agent, or their combination, for the core material to be dried well, protected and have sufficient release times and solubility.

1.4. Application of plant-based ingredients for enrichment of food / *Augu izcelsmes izejvielu izmantošana pārtikas bagātināšanai*

1.4.1. Functional plant-based ingredients / *Funkcionālās augu izcelsmes izejvielas*

Functional properties of fermented vegetable juices are combined with several benefits, such as probiotics, vitamins, minerals and bioactive compounds (Coskun, 2017; Janiszewska-

Turak et al., 2022). However, in fermented beetroot juice, as observed by Janiszewska-Turak spray-drying does not always conform to the standards for lactic acid bacteria (LAB) count, to qualify as probiotics (Janiszewska-Turak et al., 2022). Also, for functional properties, development of new plant-based food ingredients is receiving tremendous attention from researchers to ensure not only physicochemical features, but also enhance the health-promoting benefits of the final product (Marcillo-Parra et al., 2021; Carpentieri et al., 2022). For example, to extract bioactive compounds from citrus peel (Wedamulla et al., 2022), agri-food by-products to enrich pasta (Carpentieri et al., 2022), or microencapsulation of extracted compounds from broccoli stalks, cauliflower and cabbage leaves (Marcillo-Parra et al., 2021).

There are numerous studies on utilisation of by-products meanwhile enhancing the functional properties of food products. The beneficial effect of various plant-based additives in bread and meat applications have been investigated before, like *Moringa peregrina* seed husk in wheat bread (Sardabi et al., 2021), melon peel juice powder (Gómez-García et al., 2022), enriched wheat bread with quinoa leaves powder (Gawlik-Dziki et al., 2009), bread enriched with mushrooms (Y. Liu et al., 2022), kale and pak choi (Klopsch et al., 2019) quinoa flour, nettle leaves (Đurović et al., 2020), green coffee, berries, lyophilized pomegranate peel in minced beef (Zhang et al., 2022), cabbage powder in mutton patties (Malav et al., 2015) and many others. Wheat bread, and also minced meat, are some of the staple foods in most parts of the world (Gawlik-Dziki et al., 2009) with a familiar and neutral taste. Enrichment of such foods with functional properties – vitamins, minerals, probiotics or fibre would gain the most benefit, because of the vast consumption (Wieca et al., 2016).

1.4.2. Salt alternatives in food applications / *Sāls alternatīva pārtikas produktos*

The awareness of diseases caused by high consumption of salt (NaCl) is rising, but, due to its functional properties scientists are working on alternatives and possibilities to reduce it in production processes. Though the use of NaCl improves texture (Tan et al., 2020), amplifies taste characteristics (Azeredo et al., 2021), ensures microbiological safety (Inguglia et al., 2018b) and other functionalities in foods. According to World Health Organization and European Food Safety Association, EU it is recommended not to exceed more than 5 grams of NaCl per day (Sodium Intake for Adults and Children) However, most often, salt consumption is exceeded in hidden form by consuming semi-finished products, such as sausages, smoked meat, cheese, bread, snacks (Beck et al., 2021; Sun et al., 2021) and even salad dressings (Sun et al., 2021) where NaCl varies from 1 – 2.3 g 100 g^{-1}.

There are numerous researches done on salt reduction and alternative solutions in food applications, like the particle size of salt – saltier mouth feel is perceived with the decreased particle size (Vinitha et al., 2020), encapsulation (for controlled release), substitutes (substitutes NaCl), replacers (replaces Na^+). The complexity of salty taste has been investigated already in 1898, and according to early analyses of Bartoshuk (Bartoshuk, 1980) the taste of salt consists of the tastes of its components – Na^+ stimulates taste buds while Cl^- boosts the salty taste having no taste of its own. Inguglia et al. state that NaCl is the saltiest and pure-taste from salts available (Inguglia et al., 2018a; Kilcast & den Ridder, 2007). Mostly we perceive salty taste by the taste buds in the oral mucosa on our tongue (Vinitha et al., 2020).

The most common salt (NaCl) replacer is potassium chloride (KCl) (Kilcast & den Ridder, 2007; Tan et al., 2020; Zhang et al., 2020) but also calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$) and ammonium chloride (NH_4Cl) have been tested ((Raseta et al., 2018)Inguglia et al., 2018a). Though it's not granted in all the food applications, giving off-flavour or bitter, metallic taste and not performing required processing and quality parameters, done by NaCl. A different method to reduce salt is to encapsulate it in order for it to dissolve only in mouth in the contact with saliva to ensure the sensory profile (Noort et al., n.d.). Salt, encapsulated in fat, releases the taste only in the mouth by inhomogeneous distribution, creating ‘salty spots’ described as Taste contrast technology and thus characterises these samples as saltier (Beck et al., 2021; Gaudette et al., 2019; Noort et al., n.d.).

Another salt substitute is notoriously known monosodium glutamate (MSG) (Inguglia et al., 2018a) delivering an umami taste that can “modulate sweet, enhance salty and suppress bitter taste simultaneously” (Wang et al., 2020) and can make the reduced-salt food palatable with a more pleasant taste, opulent intensity and softer mouthfeel. Umami attributes naturally occur in some of the traditional foods, usually fermented animal- or plant-based, protein consisting, products (Gaudette et al., 2019; Wang et al., 2020).

There are studies done on seaweed as a salt substitute in food applications, but sensory qualities set the limitations (Gullón et al., 2021; Véliz et al., 2022; Vilar et al., 2020). Sauerkraut juice, used in this study is obtained from sauerkraut fermented with 1.7% of NaCl. Therefore, obtained products dehydrated and concentrated sauerkraut juice were tested in food applications substituting salt. To the best of our knowledge, there is no studies done before on using sauerkraut juice, DSJ or CSJ as a salt substitute.

Based on previous studies of literature, it is necessary to investigate sauerkraut juice products in food aplications and their beneficial properties.

1.4.3. Methods for evaluation of food enriched with plant based ingerdients / *Ar augu izcelsmes sastāvdaļām bagātinātas pārtikas novērtēšanas metodes*

Sensory evaluation methods

Common taste characteristics of sauerkraut are sour, sweet, salty, bitter, spicy and off taste (Major et al., 2022; Satora et al., 2021). Sauerkraut is widely used not only as a side dish, but is also valued as a flavour enhancer, and therefore is appreciated for its sensory characteristics (Major et al., 2022).

However, to the best of our knowledge, sensory evaluation for the sauerkraut juice application in food has not been carried out.

There are two cluster methods in sensory methodology – analytical and consumer methods. The analytical methods use expert groups to collect information about the product, whereas the consumer method is a subjective evaluation of the product (“Overview of Applicable Sensory Evaluation Techniques,” 2017).

The most common consumer method, amongst others, is hedonic scaling, or affective responses (Cardello & Jaeger, 2010), method developed in the United States Armed Forces to measure the food preferences of US soldiers (“Overview of Applicable Sensory Evaluation Techniques,” 2017). It is a bipolar scale that surveys the emotional reaction or the perception of the product, with like and dislike on each end, and neutral in the middle, and measures the sensation magnitude (Cardello & Jaeger, 2010). A hedonic scaling of consumer perception is widely used in bread and meat sensory evaluation of taste, texture, aroma and overall liking (Fayaz et al., 2021; Lobo & Ferreira, 2021; Martins et al., 2021), in particular to evaluate salt reduction and/or partially substituting ingredients with more functional options.

Rate-all-that-apply (RATA) and check-all-that-apply (CATA) is another sensory evaluation method. It is based on the list of terms or attributes, presented to the panellists and they are asked to check all those that apply to the sample (Vidal et al., 2018). In RATA test/question, panellists are asked to indicate if the terms or attributes apply to the sample, and if so, to rate the intensity using a 3 to 5 - point structured scale. The list of terms or attributes, used in RATA or CATA, is based on previous, analytical research (Ares et al., 2014). There are several descriptive methods to determine the list of attributes used in sensory evaluation (García-Gómez et al., 2022). In a free-choice profiling, an expert group characterised the sample using any words to evaluate sensory profile (Williams & Langron’, 1984), a method particularly significant to understand the perception and description of a new, innovative product.

Evaluation of products *in vitro*

In light of the health-promoting properties of fermented foods, in vitro experiments were conducted to assess the bioaccessibility of sauerkraut juice and its derivatives. The impact of sauerkraut juice was examined in vitro using commonplace food items such as minced meat and wheat bread, which is a ubiquitous and neutral-tasting staple in most regions of the world (Gawlik-Dziki et al., 2009; Y. Liu et al., 2022). Foods enriched with functional properties, such as sauerkraut juice, would be particularly advantageous due to their widespread consumption (Wieca et al., 2016).

Notwithstanding the potential benefits of plant-based bioactive compounds, their susceptibility to degradation under environmental conditions and instability in the harsh gastric environment can limit their therapeutic potential. To mitigate these challenges, spray-drying technology can be employed to encapsulate the core material with a protective wall material, thereby preserving the bioactive compounds from premature degradation and facilitating their controlled release (Jafari et al., 2023; D. Zhang et al., 2022). Encapsulation has been shown to be effective in enhancing the release of polyphenols from encapsulated fruit juices, resulting in a positive impact on simulated gastrointestinal tract conditions (Jafari et al., 2023).

The bioaccessibility (BAC) of bioactive compounds can be evaluated by simulating the gastrointestinal tract (GIT) to assess their release from a substance and subsequent availability for absorption (Mackie et al., 2020; Minekus et al., 2014). BAC is typically determined by comparing the concentration of bioactive compounds before and after passage through the GIT (Jakubczyk et al., 2021). Recent research has highlighted the nutritional value of DSJ (Jansone et al., 2022), underscoring the potential benefits of incorporating this ingredient into food products and subjecting it to in vitro testing to explore its health-promoting properties as a functional ingredient.

A controlled simulated gastrointestinal digestion *in vitro* has been developed in order to understand what kind of changes food undergoes after ingestion. *In vivo*, or human clinical studies, is the ‘golden standard’ to assess and evaluate bioavailability and bioaccessibility of micro- and macronutrients; however, they are challenging because of the ethical, financial and technical issues (Li et al., 2019; Xavier & Mariutti, 2021). Besides, every individual is different with its unique microbiome and thus, the obtained results are with poor repeatability. Therefore, studies *in vitro* that mimic human gastrointestinal digestion, are widely used (Li et al., 2019).

Simulated gastrointestinal digestion usually consists of oral, gastric and small intestinal phases, recreating biochemical conditions – temperature, pH, enzymes, bile salts as well as parameters like duration of each digestion step, amount and kind of enzymes, agitation speed and amount of food sample, as shown in Figure 1.6. (Li et al., 2019; Minekus et al., 2014).

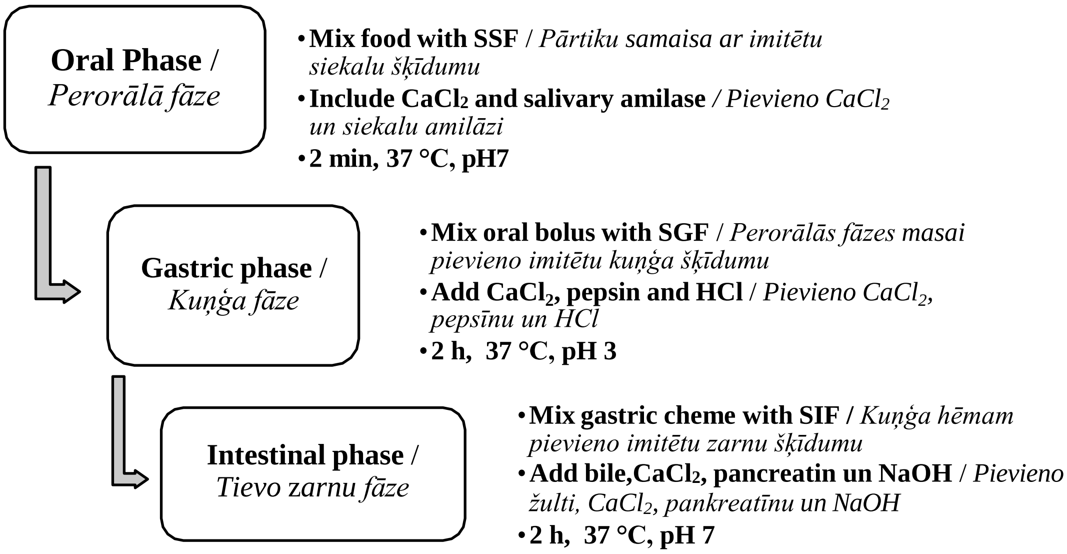

Fig. 1.6. **Scheme of simulated gastrointestinal digestion. SSF – simulated saliva fluid; SGF – simulated gastric fluid; SIF – simulated intestinal fluid /**
1.6. att. Imitētas gremošanas sistēmas in vitro, darbības shēma

In the oral phase, a simulated salivary solution (SSF), is mixed with 1 to 5 grams of food and simultaneously minced and stirred to mimic the chewing activity in the mouth. The phase is recommended to be 2 minutes long at 37 °C (Minekus et al., 2014).

In the gastric phase, a simulated gastric fluid (SGF) is added to the oral bolus along with porcine pepsin, $CaCl_2$ and HCl, to reduce pH to 3. The duration of this phase is recommended at 2 hours at 37 °C with a continuous easy mixing during digestion (Minekus et al., 2014).

In the intestinal phase, a simulated intestinal fluid (SIF) is added to the gastric cheme, along with bile, pancreatin, CaCl2. NaOH is added to neutralise pH to 7. The duration of this phase is recommended at 2 hours at 37 °C, with a continuous easy mixing (Minekus et al., 2014).

After all the digestion phases, the samples are transferred into plastic zip lock bags and frozen to terminate the enzymatic reaction.

Summary of literature review / *Literatūras apskata kopsavilkums*

White cabbage, *Brassica oleracea* subsp. *oleracea,* is globally important vegetable due to its availability, cheapness, and consumer preferences.

There are various factors that can influence the chemical and nutrient composition of white cabbage - abiotic, biotic and agronomic practice. Therefore, the exact amounts of specific compounds cannot be definitively stated due to variations in results from different times, regions, and crops.

In general, white cabbage is low in calories, protein and fat content, moderate carbohydrate content, and essential amino acids. It is a valuable source of vitamins such as vitamin C, vitamin A, and vitamin K, minerals such as calcium, potassium, and magnesium, and trace elements such as manganese, iron, zinc, copper, and selenium. Additionally, it contains polyphenols and flavonoids. The most abundant bioactive substances in white cabbage are glucosinolates.

Fermentation is a natural process that involves the chemical breakdown of complex organic substances into simpler compounds by microorganisms, resulting in improved nutritional value, sensory quality, and health-promoting properties of the final product. The traditional process of producing sauerkraut, relies on spontaneous fermentation with indigenous lactic acid bacteria present on cabbage leaves and is influenced by factors such as salt concentration and type, temperature, vegetable freshness, natural microflora and fermentation time.

Sauerkraut contains organic acids, sugars, vitamins, minerals, and phenolic compounds. The taste and flavour of sauerkraut are influenced by factors such as the variety, amount of salt used, and fermentation and storage conditions. LAB strains and their metabolism of lipids, amino acids, and glucosinolates also play a role in the formation of the specific sauerkraut flavour. The aroma of sauerkraut is characterised by pungent, fermented, vegetable-specific, and sulphur notes. The breakdown of glucosinolates during fermentation also produces isothiocyanates, which are responsible for the pungent aroma of sauerkraut and have nutritional benefits such as exhibiting anticancer properties and chronic disease prevention.

Sauerkraut juice, a by-product of the fermentation process, is rich in valuable compounds, but little research has been done on its utilisation. To address this, sustainable solutions for preserving and utilising sauerkraut juice, such as evaporation or spray-drying, need to be explored.

The evaporation process is used to prolong the shelf life of liquids by reducing water activity and increasing microbiological stability. This also reduces packaging, storage, and transportation costs. Fruit juices are the major category for concentration, however vegetable juices have been less studied. There are various techniques and methods available to achieve a concentrated product with desirable characteristics and outcome.

Spray-drying is a common technology used for dehydration and microencapsulation in the food industry. It involves converting a liquid sample into small droplets using an atomizer, which are then dried by hot air to form dry solid particles. Sticky materials, such as sauerkraut juice, can be challenging to spray-dry, but this issue can be solved by homogenising the core and carrier agent. The carrier agent usually has a higher molecular weight and forms an external layer on the drying particle to change the stickiness of its surface.

There is ongoing research on alternatives to reduce salt (NaCl) in food production since its consumption exceeds recommended limits causing health risks. Potassium chloride (KCl) is the most common salt (NaCl) replacer, but also seaweed has been studied as a salt substitute, however, sensory qualities have limitations. Sauerkraut juice has not been studied before as a salt substitute but was tested in food applications by dehydrating and concentrating it.

The health-promoting properties of sauerkraut juice and its derivatives as functional ingredients in food products can be investigated through in vitro simulation of the gastrointestinal tract to evaluate their bioaccessibility and potential health benefits.

Baltais galviņkāposts, Brassica oleracea subsp. oleracea, ir nozīmīgs dārzenis visā pasaulē, pateicoties tā pieejamībai, patērētāju vēlmēm un zemajai cenai.

Galviņkāpostu fizikāli ķīmisko un uzturvielu sastāvu var ietekmēt dažādi faktori – abiotiskie, biotiskie un agronomiskā prakse. Tāpēc konkrētu savienojumu precīzu daudzumu nevar noteikt, jo rezultāti atšķirsies, veicot analīzes dažādos laikos, reģionos un dažādām ražām.

Kopumā baltais galviņkāposts ir ar zemu kaloriju, olbaltumvielu un tauku daudzumu, mērenu ogļhidrātu saturu un neaizvietojamām aminoskābēm. Tas ir vērtīgs vitamīnu, piemēram, C vitamīna, A un K vitamīnu, minerālvielu, piemēram, kalcija, kālija un magnija, un mikroelementu, piemēram, mangāna, dzelzs, cinka, vara un selēna avots. Turklāt tas satur polifenolus un flavonoīdus, un visvairāk sastopamās bioaktīvās vielas ir glikozinolāti.

Fermentācija ir dabisks process, kas mikroorganismu darbības ietekmē sadala sarežģītas organiskās vielas vienkāršākos savienojumos, kā rezultātā uzlabojas gala produkta uzturvērtība, veselību veicinošās un garšas īpašības. Uz kāpostu lapām esošās pienskābes baktērijas nodrošina tradicionāli skābētu kāpostu ražošanas procesu, ko dēvē par spontāno fermentāciju, un to ietekmē tādi faktori kā sāls koncentrācija un veids, temperatūra, dārzeņu svaigums, dabiskā mikroflora un fermentācijas laiks.

Skābēti kāposti satur organiskās skābes, cukurus, vitamīnus, minerālvielas un fenola savienojumus. Skābētu kāpostu garšu un aromātu ietekmē tādi faktori kā šķirne, sāls *koncentrācija, kā arī fermentācijas un uzglabāšanas apstākļi. Specifisko skābētu kāpostu garšu veido pienskābes baktēriju un lipīdu, aminoskābju un glikozinolātu metabolisms. Skābētu kāpostu aromāts ir ass, raudzēts, dārzeņiem raksturīgs un ar sēram raksturīgām niansēm. Glikozinolātu sadalīšanās fermentācijas laikā rada arī izotiocianātus, kas nodrošina skābētu kāpostu aso aromātu un paaugstina to uzturvērtību, nodrošinot pretvēža īpašības un hronisku slimību profilaksi.*

Skābētu kāpostu sula, kas ir fermentācijas procesa blakusprodukts, ir bagāta ar vērtīgiem savienojumiem, taču par tās izmantošanu ir maz pētījumu. Lai to risinātu, ir jāizpēta ilgtspējīgi risinājumi, kā ietvaice vai kaltēšana izsmidzinot, skābētu kāpostu sulas konservēšanai un tālākai izmantošanai.

Iztvaikošanas procesu izmanto, lai paildzinātu šķidrumu glabāšanas laiku, samazinot ūdens aktivitāti un palielinot mikrobioloģisko stabilitāti. Tas arī samazina iepakojuma, uzglabāšanas un transportēšanas izmaksas. Augļu sulas ir galvenā koncentrēšanās kategorija, savukārt dārzeņu sulas ir mazāk pētītas. Lai iegūtu koncentrētu produktu ar vēlamām īpašībām un iznākumu, ir pieejamas dažādas metodes un tehnoloģijas.

Izsmidzināšana ir ierasta tehnoloģija, ko izmanto dehidratācijai un mikroiekapsulēšanai pārtikas rūpniecībā. Tas ietver šķidrā parauga pārvēršanu nelielos pilienos, izmantojot atomu, ko pēc tam kaltē ar karstu gaisu, lai veidotu sausas, cietas daļiņas. Lipīgus šķidrumus, piemēram, skābētu kāpostu sulu, var būt izaicinoši dehidrēt, tomēr tas ir risināms, homogenizējot izejmateriālu un nesējvielu. Nesējvielas ir ar lielāku molekulmasu un tās veido kapsulu - izžūstošās daļiņas ārējo slāni, lai mainītu tās virsmas lipīgumu.

Pētījumi par alternatīvām sāls (NaCl) samazināšanas iespējām pārtikas ražošanā ir nerimstoši, jo tā patēriņš pārsniedz ieteicamās robežas, kas apdraud veselību. Kālija hlorīds (KCl) ir visbiežāk sastopamais sāls (NaCl) aizstājējs, bet arī jūras aļģes ir pētītas kā sāls alternatīva, tomēr šeit ir ierobežojumi sensoro īpašību dēļ. Skābētu kāpostu sula līdz šim nav pētīta kā sāls aizvietotājs, tāpēc to dehidrējot un koncentrējot, iegūtie produkti tika testēti pārtikas produktos.

Skābētu kāpostu sulas un tās produktu veselību veicinošās īpašības var izpētīt, simulējot kuņģa-zarnu trakta darbību in vitro, lai novērtētu to bioloģisko pieejamību un iespējamos ieguvumus veselībai.

2. MATERIALS AND METHODS / *MATERIĀLI UN METODES*

2.1. Time and place of the research / *Pētījumu laiks un vieta*

Experimental work was carried out during the time period from 2018 to 2023 in scientific and industrial institutions.

In Latvia University of Life Sciences and Technologies, Faculty of Food Technology following experimental work was carried out.

- In the technological process and equipment laboratory - sauerkraut juice was concentrated and spray-dried.
- In the scientific laboratory - volatile and phenolic compounds, antioxidant activity, pH, dry matter and moisture content were analysed.
- In the flour and confectionery laboratory, bread samples were prepared.
- In the scientific laboratory of microbiology, enumeration of microorganisms.
- In the sensory laboratory, sensory evaluation of the bread and meat, olive oil and sour cream samples.
- In the fruit and vegetable processing pilot plant, product samples were prepared.
- In the biotechnology laboratory *in vitro* gastrointestinal digestion was carried out.
- In the department of chemistry, in the scientific laboratory of the chemistry of natural substances, organic acid content was determined.
- In the department of Smart Technologies, polyphenols in sauerkraut juice and its products were identified.

- “J.C. Hamilton” Baltic Ltd. Laboratory provided analyses of micro and macro nutrients.
- “Dimdiņi” Ltd – fermentation of sauerkraut under industrial conditions, concentration of sauerkraut juice.
- Horizontal spray-drying Tecoma Drying Technology SRL, Italy.
- Industrial trial for dehydrated and concentrated sauerkraut juice application in bread and meat products in “Flora” Ltd and “Margret” Ltd.

2.2. Description of materials / *Materiālu raksturojums*

Three varieties of fresh white cabbage (*Brassica oleracea* var. *capitata*) ‘Selma’, ‘Ramkila’ and ‘Kiloplons’ were grown in the test fields of farming company “Dimdiņi Agro” Ltd (Gulbenes district, Lizums parish). The usual agricultural practice is hoisting and weeding once in a season. Soil is loamy. Fertilization: N (nitrogen), P_2O_5 (phosphorus), K_2O (potassium) and calcium-ammonium nitrate. Vegetation period for varieties ‘Selma’ and ‘Kiloplons’ is 135 days. Average annual air temperature and total precipitation of Gulbene district[7] in the period from 2015 to 2021 is shown in Fig.2.1. According to Latvian Environmental Geology and Meteorology Center, climatic conditions in 2020 were warm and sunny (7% below the norm), however 2018 was the driest year in meteorological history (32% below the norm). According to Chandra -Hioe and Moreb, dry, sunny and warm climatic conditions promotes biosynthesis of antioxidans (Chandra-Hioe et al., 2017; Moreb et al., 2020) also water stress can be related to synthesis of bioactive compounds (Kusznierewicz, Bartoszek, et al., 2008a; Björkman et al., 2011).

[7] Latvijas vides ģeoloģijas un meteoroloģijas centrs. [online] [vieved on 23. March 2023]. Retrieved from https://klimats.meteo.lv/pasvaldibu_apskati/novads/gulbenes_novads/

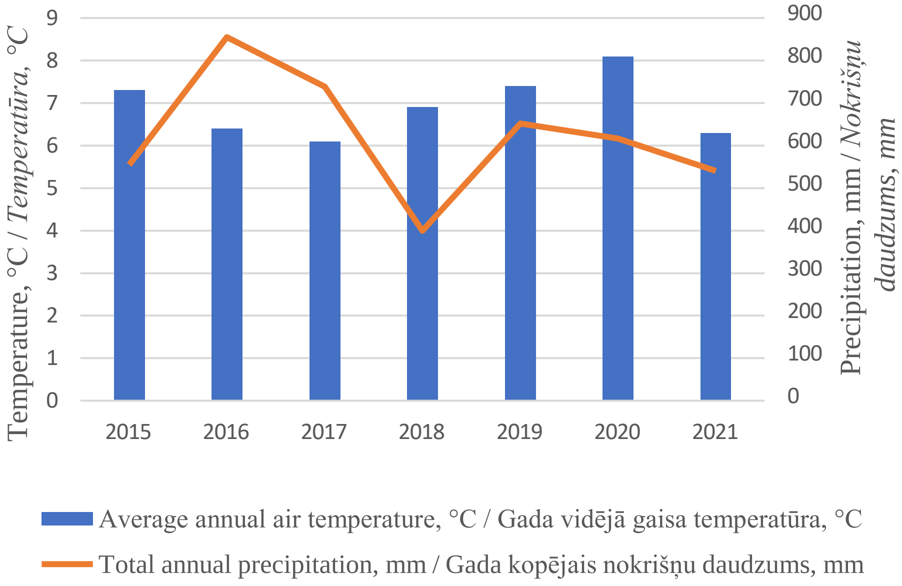

Fig. 2.1**. Average annual air temperature and total precipitation of Gulbene district in the period from 2015 to 2021 /**
2.1. att. Gulbenes novada gada vidējā gaisa temperatūra un kopējais nokrišņu daudzums laika posmā no 2015. līdz 2021. gadam

Sauerkraut juice from the same varieties 'Selma', 'Ramkila' and 'Kiloplons', was obtained from production company "Dimdiņi" Ltd. Fresh cabbage and sauerkraut juice was delivered in November 2018, August 2019, November 2020. Due to a large variation of tested samples and materials used, description of materials is added after each descriptive stage.

2.3. Research structure / *Pētījuma struktūra*

Research has been carried out in several stages that are represented in Figure 2.2 and all are discussed in detail below.

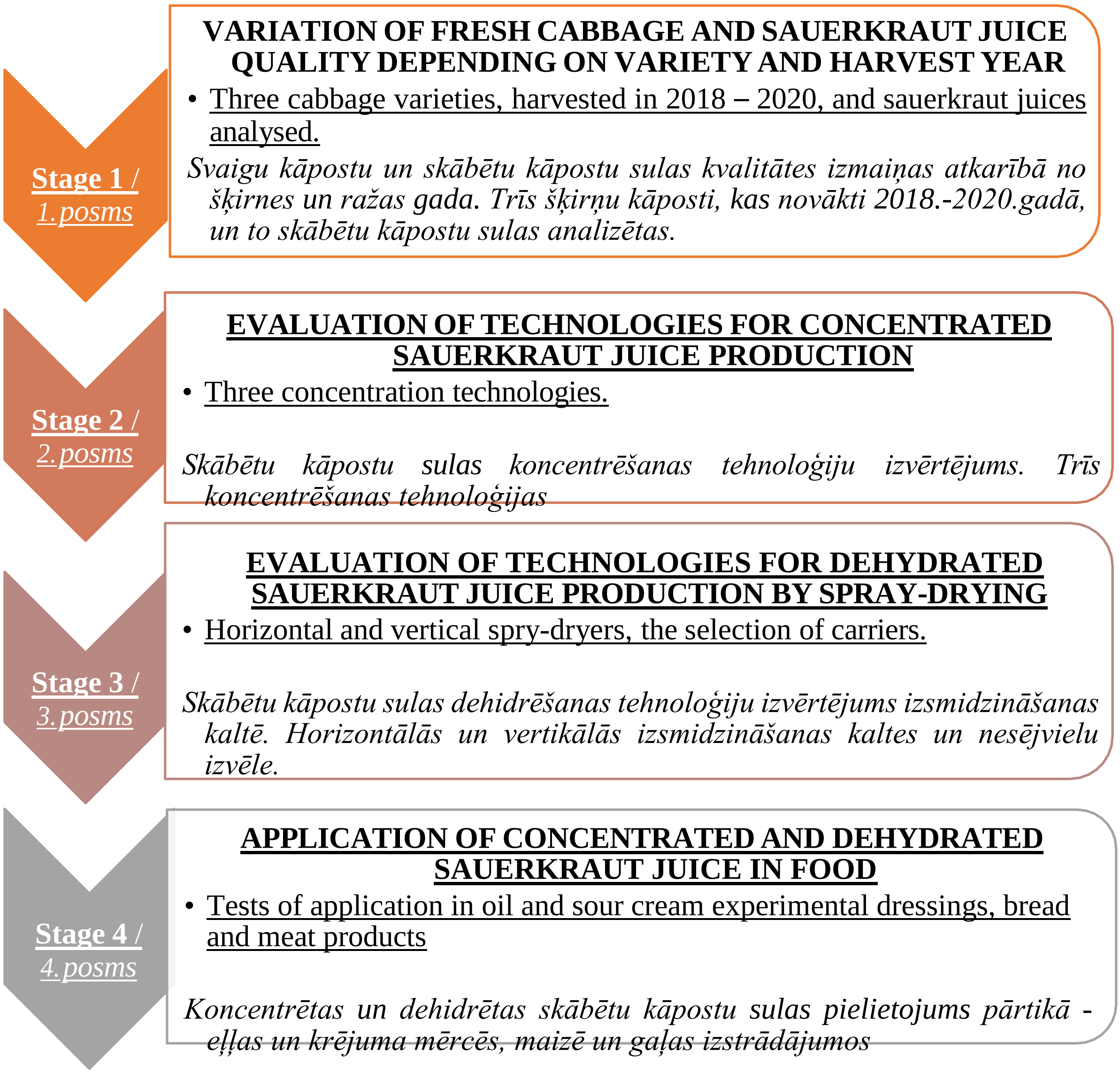

Fig. 2.2. **The research stages** /
2.2. att. Pētījuma posmi

Further characterization of stages is presented below.

2.3.1. Stage 1 - Fresh cabbage and sauerkraut juice characteristics / *1. posms - Svaigu un skābētu kāpostu sulas raksturojums*

The aim of the first stage was to analyse the raw material – white cabbage and subsequently, the juice of the sauerkraut of the same raw material. The following steps, shown in Figure 2.3. were taken to accomplish the first stage.

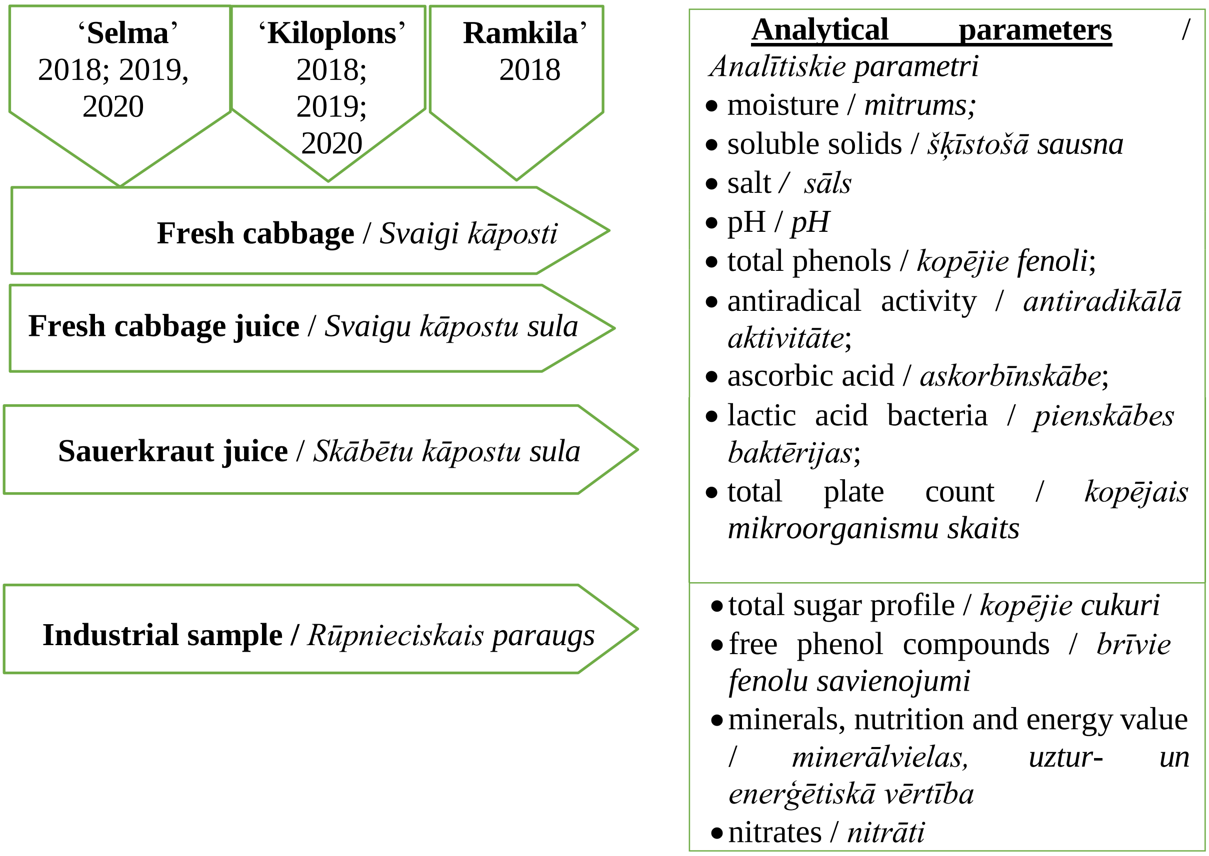

Fig. 2.3. **Structure of research stage 1 - Characteristics of fresh and sauerkraut juice of different varieties and harvest years /**
2.3. att. Pētījuma 1. posma struktūra - Dažādu šķirņu un ražas gadu svaigu un skābētu kāpostu sulas raksturojums

White cabbage was grown in the test fields of "Dimdiņi Agro" Ltd in 2018.,2019.,2020. It is located in Lizuma parish, Gulbene district and is a family owned company. "Dimdiņi Agro" Ltd is one of the largest vegetable growing and processing companies in the Baltic States, specialising in growing cabbage since 1992. Varieties were chosen for the project (Nr.18-00-A01612-000020) based on their quality and agrotechnical condition. However, the 'Ramkila' variety was grown in 2018 only and was excluded from further cultivation and research.

Three cabbage heads from each variety 'Selma', 'Kiloplons', 'Ramkila' were used in the experiments. The bruised, outer leaves from the cabbage heads were removed and a segment (3 – 5 cm wide) from each head was cut out from top to bottom including middle, the core was removed. For analyses of fresh cabbage, pieces of each segment, cut lengthwise, were minced with a hand blender MultiQuick 5 Vario (Braun GmbH, Germany). For the analyses of fresh cabbage juice, it was extracted from the pieces of each segment, with a masticating slow juicer Easyline, Villa - Verucchio model ELCJE620323M.

Sauerkraut juice from the fermented cabbage of the same varieties was delivered at the same time in 1 L bottles and stored in the refrigerator at 4 ± 1 °C for 5 days. "Dimdiņi" Ltd ferments cabbage in a traditional way – shredding cabbage, mixing with 1.7% salt, 2% shredded carrot and 1% caraway seeds, sealed and let to ferment for 5 days at + 16 – 20 °C. Then stored at 3.8 ± 0.01 °C.

Moisture content, total phenol content, antiradical activity and ascorbic acid content, and microbiological analyses were carried out for fresh cabbage and fresh cabbage juice.

Moisture content, pH, salt content, total phenol content, antiradical activity, ascorbic acid, volatile compounds and microbiological analyses were carried out for sauerkraut juice.

2.3.2. Stage 2 - Production of concentrated sauerkraut juice / *2. posms - Koncentrētas skābētu kāpostu sulas ieguve*

The aim of the second stage was to compare and evaluate available evaporation technologies. The following steps, shown in Figure 2.4. were taken to accomplish this stage.

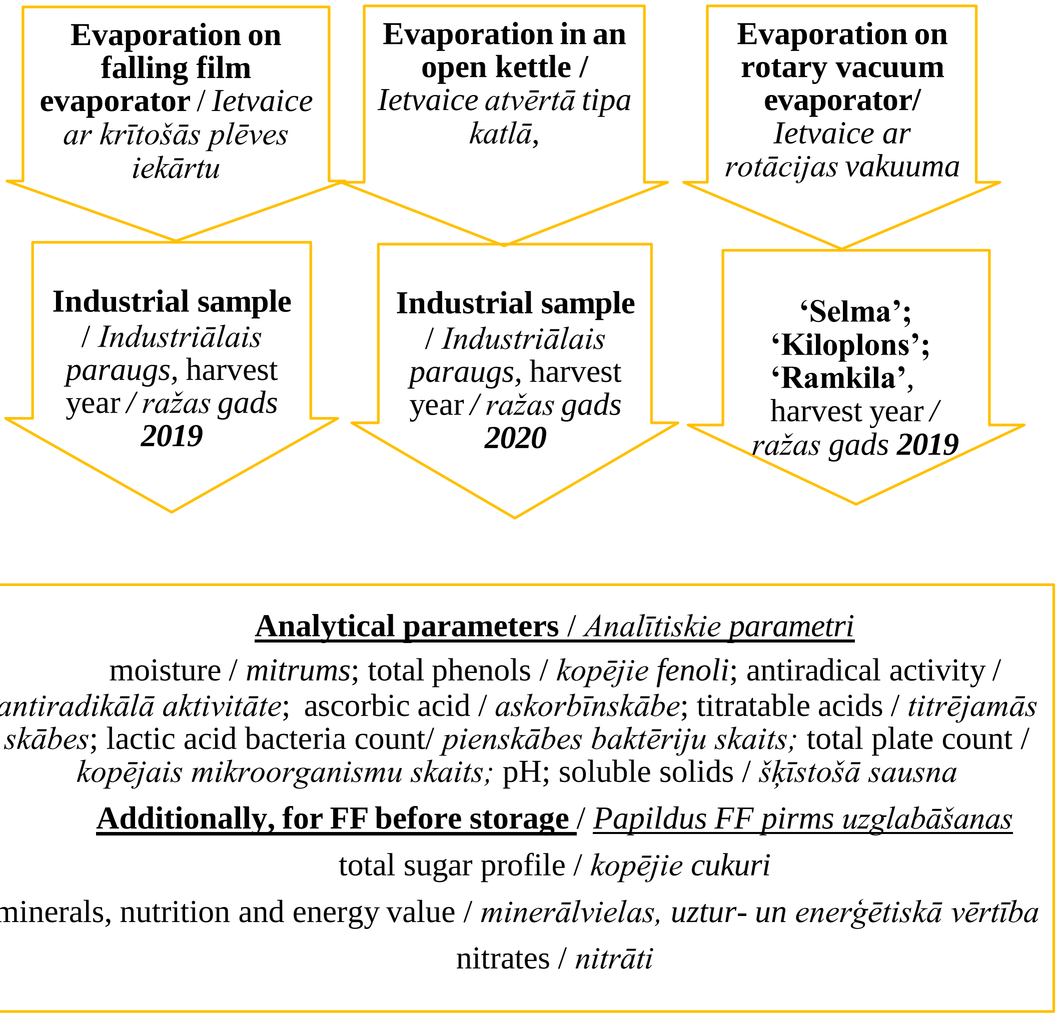

Fig. 2.4. **Structure of research stage 2 - Production of concentrated sauerkraut juice /**
2.4. att. Pētījuma 2. posma struktūra - Skābētu kāpostu sulas koncentrāta ieguve

Evaporation on rotary vacuum evaporator / *Ietvaice ar rotācijas vakuuma iekārtu*

The concentration of sauerkraut juice was carried out on laboratory scale rotary evaporator Heidolph Laborota 4000 Efficient. Fig. 2.5.

Fig. 2.5. **Rotary evaporator Heidolph Laborota 4000 Efficient /**
2.5. att. Rotācijas ietvaicētājs Heidolph Laborota 4000 Efficient

Sauerkraut juice of varieties 'Selma', 'Ramkila', 'Kiloplons' were delivered and evaporated in January 2020. The initial and final soluble solids for sauerkraut juice were determined with digital refractometer DR301 – 95 (ISO 2173: 2003). Refractometer is calibrated with deionized water before measurement. The scheme of evaporation process is shown in Fig. 2.6.

Sauerkraut juice / *Skābētu kāpostu sula*
volume / *tilpums 600 ml*

⇩

Rotary - vacuum evaporation / *Rotācijas vakuumietvaicēšana*
the time of evaporation / *ietvaicēšanas ilgums* 4 h
evaporation temperature / *ietvaicēšanas temperatūra* 45 °C
60 rpm / *apgr. min^{-1}*
60 – 70 mbar

⇩

Concentrated sauerkraut juice / *Koncentrēta skābētu kāpostu sula*

Fig. 2.6. **The process of rotary vacuum evaporation of concentrated sauerkraut juice juice** /
2.6. att. Skābētu kāpostu sulas ietvaicēšanas norise rotācijas vakuuma ietvaicē

The concentration to approx. 30 °Brix was chosen according to industrial equipment in "Smiltenes piens" Ltd (Smiltene, Latvia), that technical specification suggested 30 – 35 °Brix.

For the concentrated sauerkraut juice total phenol content, antiradical activity, titratable acids, pH, soluble solids, and microbial analyses (total plate and lactic acid bacteria count) were carried out.

A falling film evaporation / *Krītošās plēves ietvaice*

Sauerkraut juice was also evaporated on a falling film evaporator FF2000 Pilot with temperature in calandria 68 °C and in separator 62 °C. Capacity 1460 kg h $^{-1}$. 2000 L of sauerkraut juice from different varieties, an industrial sample (a juice collected from the production of sauerkraut, no specific variety), was delivered to a production plant "Smiltenes piens" Ltd (Smiltene, Latvia) on February, 2020. The juice was evaporated to 34.3 °Brix, then cooled down, filled in polyethylene bags and stored in the refrigerator at 4 ± 1 °C.

The juice, concentrated on a falling film evaporator, was analysed in two periods of time – March 2020 and, after 6 months of storage at 4±2 °C, in September 2020.

For the obtained concentrated sauerkraut juice moisture content, pH, total soluble solids, total phenol content, antiradical activity by DPPH• and $ABTS^+$, ascorbic acid, total sugars, nutrition and energy value, minerals and nitrates were determined and microbiological (lactic acid bacteria, total plate count) analyses were carried out.

Evaporation in an open kettle / *Ietvaice atvērtā tipa katlā*

Evaporation was carried out in "Dimdiņi" Ltd premises in an open kettle, in September 2020. 100 L of sauerkraut juice from different varieties (an industrial sample) was evaporated at 100 °C and the obtained concentrate was 17.9 °Brix. It was then cooled down, refrigerated at 4 ± 2 °C and delivered in 1 L bottles for analyses.

2.3.3. Stage 3 - Production of dehydrated sauerkraut juice / *3. posms - Dehidrētas skābētu kāpostu sulas ieguve*

The aim of the third stage was to compare and evaluate spray-drying technologies. The following steps, shown in Figure 2.7. were taken to accomplish this stage.

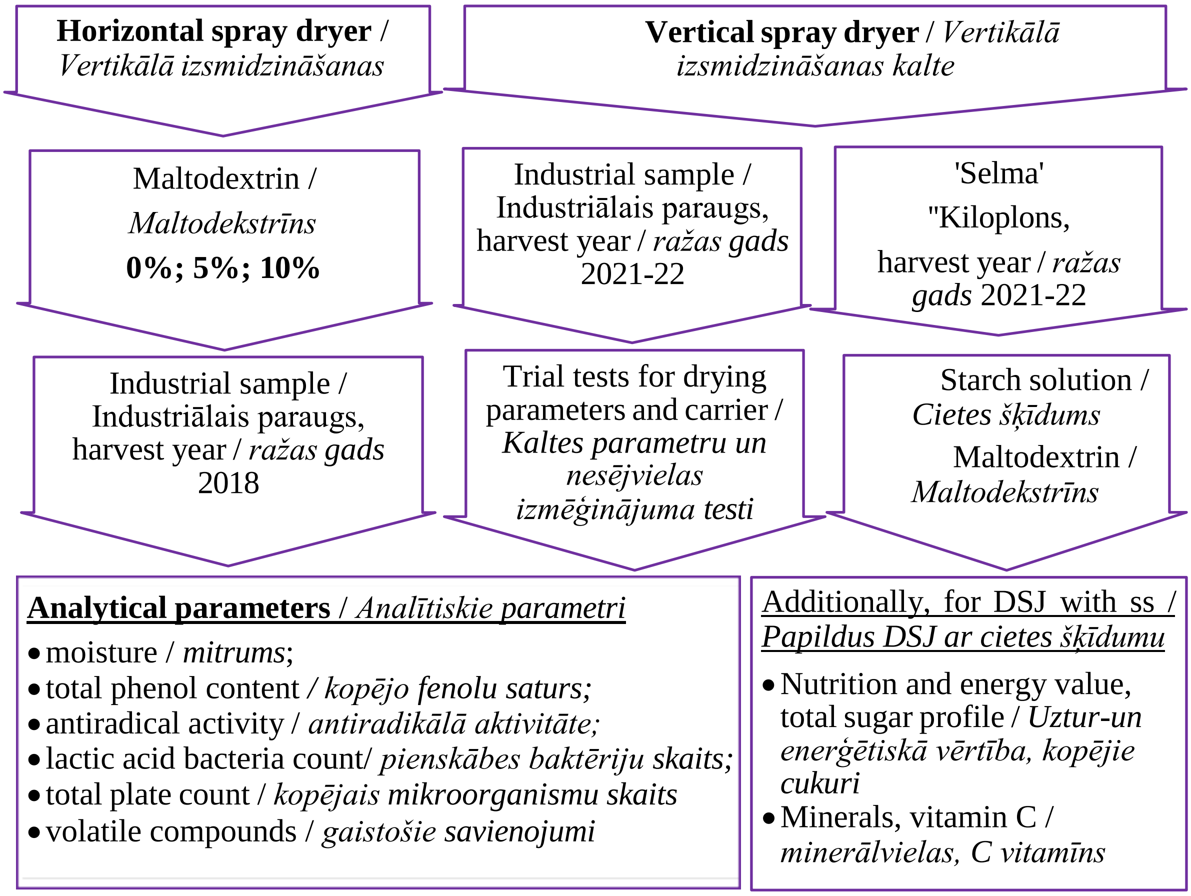

Fig. 2.7**. Structure of research stage 3 - production of dehydrated sauerkraut juice** / *2.7. att. Pētījuma 3. posma struktūra, dehidrētas skābētu kāpostu sulas ieguve*

For the horizontal spray-drying of sauerkraut juice, a 200 L barrel of industrial sample, from a cabbage production plant "Dimdiņi" was collected after producing sauerkraut by a classic technology used in the fermentation, and delivered to Tecoma Drying Technology SRL in 2018. It was spray dried in a horizontal spray dryer Gatedryer Turbo 150 GGI FB PT (Maranello, Italy)) with an expected hourly input of ± 15 kg h^{-1} inlet/outlet temperature 160/75 °C, and expected evaporation capacity 135 kg h^{-1}. Different maltodextrin (with a dextrose equivalent DE 7-13) concentrations (0, 5, and 10 %) were used and $CaCO_3$ was added to neutralise pH, as explained in Table 2.1. After spray-drying, the samples were kept in sealed plastic containers, in the dark at 22 ±1 °C temperature.

For a laboratory-scale vertical spray-drying, preliminary work was done with an industrial sample to determine the most suitable carrier agent and drying parameters for sauerkraut juice in order to avoid stickiness and forming of caramelised agglomerates. Various maltodextrin (DE 12 – 16) concentrations (5%; 10%; 20%) according to dry weight of sauerkraut juice were tested. Also, different carrier agents, like inulin, polydextrose, dextrose, their combination and concentrations were tested.

Table 2.1. / *2.1. tabula*

Horizontally spray-dried sample abbreviations and amount of maltodextrin and calcium carbonate used / *Horizontālās izsmidzināšanas kaltē iegūto paraugu apzīmējumi un lietoto piedevu koncentrācija*

Concentration of addition / *Piedevas koncentrācija*	**Sample** / *Paraugs*			
	1MD10	**2MD10**	**3MD5**	**4MD0**
Maltodextrin on total mass / *Maltodekstrīns uz kopējo masu*, %	10	10	5	0
Calcium carbonate / *Kalcija karbonāts*, $CaCO_3$ g^{-1} L	5	3	5	5

As well as various temperature regimes (130 – 180 °C outlet), feed flow rate and aspiration capacity were examined. The conducted experiments proved to be abortive resulting in sticky, not collectible dehydrate, as seen in Fig. 2.8.

Fig. 2.8. **Vertically spray-dried sauerkraut juice with maltodextrin**
2.8. att. Vertikālā izsmidzināšanas kaltē kaltēta skābētu kāpostu sula ar maltodekstrīnu

Alternative method with hydrolysed potato starch (Chempur Starch soluble pure p.a.) was carried out. 20 g of starch and 400 g of deionized water was heated at 90 ± 2 °C for 30 min and left overnight at room temperature as described by L. Tomsone (2020). Starch solution of concentration 1:20 (deionized water) was used.

Sauerkraut juice was mixed with starch solution and/or maltodextrin according to the design described in Fig. 2.9. and homogenised throughout the drying process on a magnetic stirrer.

The mixture was fed into warmed up Büchi Mini Spray Dryer B – 290 (Büchi, Flawil, Switzerland) with the feed rate 35 mL min^{-1}, Inlet and outlet temperatures for drying with starch solution 140°C and 60°C, and for drying with starch solution and maltodextrin combination 150°C and 70°C, accordingly, spray gas flow 35 L h^{-1}. The dried samples were collected and stored in plastic bags in a desiccator.

Sauerkraut juice, variety ‘Selma’ and ‘Kiloplons’ / *Skābētu kāpostu sula, šķirne ‘Selma’ un ‘Kiloplons’*	
⇩	⇩
75 g starch solution + 50 g sauerkraut juice / *75 g cietes šķīdums + 50 g skābētu kāpostu sula*	50 g starch solution + 50 g sauerkraut juice + 3 g maltodextrin / *50 g cietes šķīdums + 50 g skābētu kāpostu sula + 3 g maltodekstrīns*
⇩	⇩
Inlet temperature 140 °C Outlet 60 °C Aspirator 65 % Flow 35 Pump 30 L h $^{-1}$.	Inlet t 150 °C Outlet 70 °C Aspirator 70 % Flow 35 Pump 30 L h $^{-1}$.
⇩	⇩
Physical, chemical and microbiological parameters / *Fikāli - ķīmiskie un mikrobioloģiskie rādītāji*	

Fig. 2.9. **The design of dehydration of sauerkraut juice /**
2.9. att. Dehidrētas skābētu kāpostu sulas ieguve

2.3.4. Stage 4 - Sauerkraut juice products in food applications / *4. posms - Skābētu kāpostu sulas produktu pielietojums pārtikā*

Trial tests for sauerkraut juice products in food applications

Dehydrated (DSJ) and concentrated (CSJ) sauerkraut juice was tested in industrial scale food applications. The use of DSJ and CSJ was tested in crisp breads containing rye and full grain oat flours, sesame, pumpkin, and sunflower seeds, as well as in rye and wheat flour moulded breads with seeds. Additionally, CSJ was tested in sausages, fresh and smoked meat products. A summary of the sauerkraut juice products used in the bread and meat test trials is presented in Table 2.2.

Table 2.2. / *2.2. tabula*

Dehydrated (DSJ) and concentrated (CSJ) sauerkraut juice quantities in industrial preparation of bread and meat test trials / *Dehidrētas (DSJ) un koncentrētas (CSJ) skābētu kāpostu sulas daudzums, gatavojot maizes un gaļas izmēģinājuma testus*

Bakery / *Maiznīca* ‘Flora’	**DSJ, %**	**CSJ, %**
Moulded bread / *Veidņu maize*	0.6	2
Crisp bread / *Sausmaizītes*	1	3 – 4
Rye bread / *Rudzu maize*		2 – 3
Meat production company / *Gaļas pārstrādes uzņēmums* ‘Margaret’	**CSJ, %**	
Fresh sausage / *Kupāti*	0.1 – 2	
Boiled sausage / *Vārītās desas*	0.1 – 2	
Fresh meat for grilling / *Šašliks*	0.1 – 1	
Semi-dried meat / *Puszāvēta gaļa*	0.1 – 4	
Smoked meat / *Kūpināta gaļa*	0.1 – 5	

These tests were carried out in the bakery 'Flora' Ltd (Krimulda district, Latvia) and meat production company 'Margret' Ltd (Jēkabpils, Latvia). The control samples used for the test trials were the company's own recipes and were not included in the thesis.

In Latvia University of Life Sciences and Technologies, various tests were conducted to determine suitable applications of concentrated and dehydrated sauerkraut juice in food. As part of testing process, dry soup mixes were experimentally prepared, including borsch, traditional sauerkraut soup, and miso soup. For the borsch mix with DSJ, dried and milled carrots, leeks, red beetroot, garlic, parsley, and spices were used. In the experiments, the vegetable mix to DSJ ratio was 3:1. However, soup mixes with DSJ were found to have a bitter and somewhat flat flavour, resulting in a decision to discontinue further studies. Soup pastes were prepared also with CSJ, dried vegetables, spices and herbs of different concentrations and the vegetable mix to CSJ ratio was 1:3. It was found that soup pastes with concentrated sauerkraut juice (CSJ) have potential for further investigation.

CSJ was also tested in experimental meat applications using pork belly and minced pork. The pork belly was prepared using two different concentrations of CSJ, specifically 10% and 20%, while the minced pork was prepared with 5% and 10% CSJ. Pork belly samples were baked in the preheated rotary oven (Sveba Dahlen, Fristad, Sweden) at 200 ± 3°C for 45 minutes, while minced meat samples were baked for 15 minutes. A five-point scale hedonic sensory evaluation was conducted on the experimental meat samples.

Sauerkraut juice products in food applications

The aim of the fourth stage was to test dehydrated sauerkraut juice in food applications – experimental dressings and in bread and meat products. The following steps, shown in Figure 2.10. were taken to accomplish this stage.

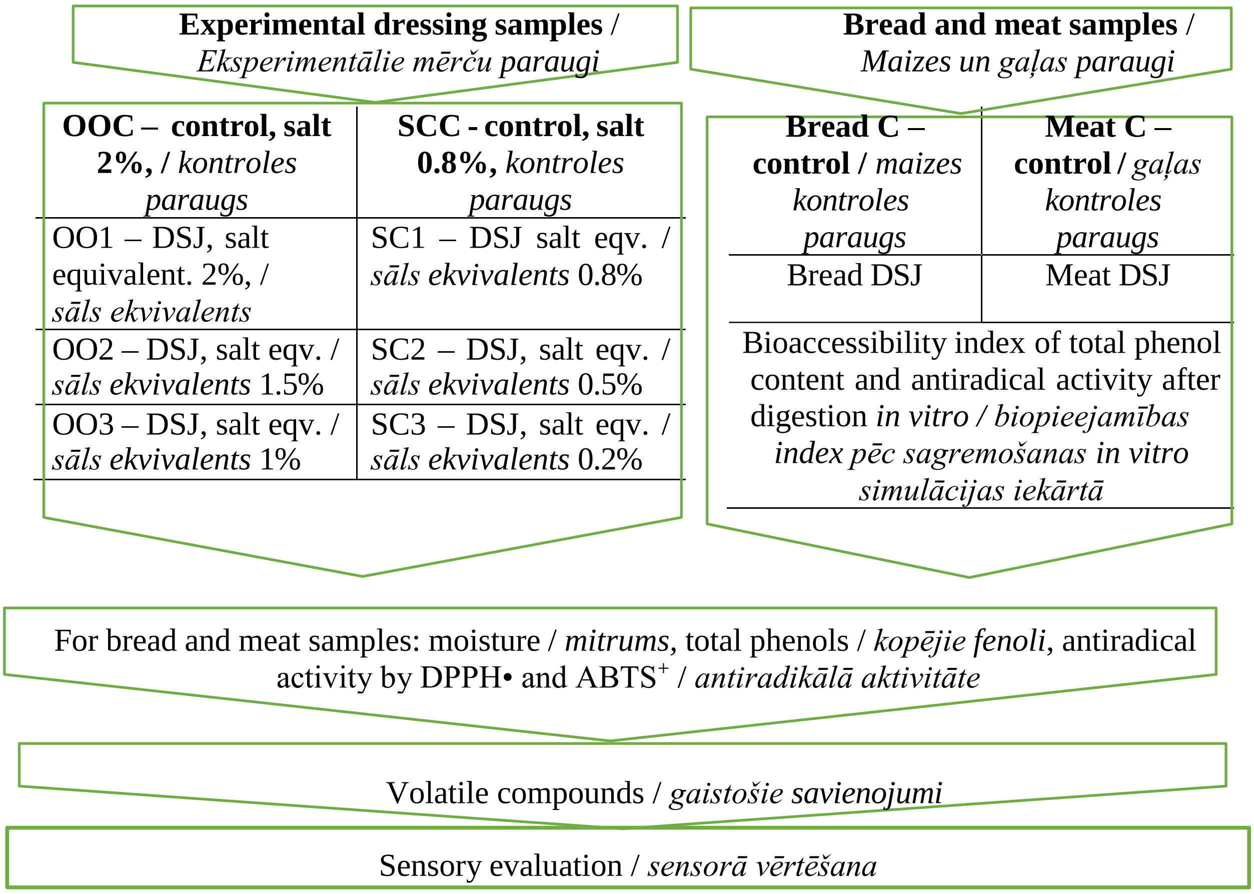

Fig. 2.10**. Structure of research stage 4 - Sauerkraut juice products in food applications** / *2.10. att. Pētījuma 4. posma raksturojums - Skābētu kāpostu sulas produktu pielietojums pārtikā*

Experimental dressing sample preparation

DSJ was tested in food application as a salt alternative. For experimental dressings with olive oil and with sour cream, commercially available salad dressings were compared, to determine salt content and list of ingredients. Due to market research, the most common dressings available are salad dressings based on olive oil and creamy garlic sauces. Commercially available dressings that were compared in this study were: Oak'a Burger garden salad dressing (Dormers Ltd., Latvia), Oak'a Burger balsamic salad dressing (Dormers Ltd., Latvia), Kraft balsamic vinaigrette (Kraft Heinz Foods Company,USA), Spilva vegetable dressing (Orkla Foods Latvia Ltd., Latvia), Spilva lemon/olive oil dressing (Orkla Foods Latvia Ltd., Latvia), and garlic sauces Heinz (Kraft Heinz Foods Company, USA), Spilva (Orkla Foods Latvia Ltd., Latvia), Hellman's (Unilever, USA), Taste Me (Sanitex Ltd, Latvia), Kitchen masters (UAB Kėdainių Konservų Fabrikas, Lithuania). In total 5 oil-based and 5 cream-based dressings were analysed. The amount of salt in experimental dressings was chosen based on research of commercially available dressings and reduced in the following samples as is described in Table 2.3.

Table 2.3. / *2.3. tabula*

The amount of NaCl and DSJ used in the experimental dressing samples and their abbreviations /
Paraugos lietotais sāls un dehidrāta daudzums un paraugu apzīmējumi

Type of dressing / *Mērces veids*	**Abbreviation /** **S***aīsinājums*	**NaCl, g 100 g^{-1}**	**DSJ salt equivalent, g 100 g^{-1}**	**DSJ, g 100 g^{-1}**
Experimental samples with olive oil / *Eksperimentālie mērču paraugi ar olīveļļu*	OOC	2.0	-	-
	OO1	-	2.0	16.7
	OO2	-	1.5	12.5
	OO3	-	1.0	8.3
Experimental samples with sour cream / *Eksperimentālie mērču paraugi ar skābo krējumu*	SC	0.8	-	-
	SC1	-	0.8	6.7
	SC2	-	0.5	4.2
	SC3	-	0.2	1.7

The salt content in the experimental samples was chosen based on the market research on similar, commercially available products – dressings. Based on these findings, maximum amount of 2.0 g 100 g^{-1} NaCl (OOC; OO1) was used in the experimental samples with olive oil and then the amount was reduced to 1.5 (OO2); 1 (OO3) g 100 g^{-1} and maximum amount of 0.8 g 100 g^{-1} NaCl (SCC; SC1) in sour cream samples were used and reduced to 0.5 (SC2); 0.2 (SC3) g 100 g^{-1}.

For dehydrated sauerkraut juice, salt equivalent was calculated as 2 grams of salt in a control sample, multiplied by 100 g and divided by 12 grams salt in 100 g DSJ.

$$Salt\ equivalent = \frac{2x100}{12} \quad (2.1.)$$

Experimental dressings were prepared using "Fratelli Mantova" olive oil, "Artiomsol" fine salt, and "Rimi" sour cream with 20% fat content.

Sensory evaluation

Sensory evaluation was carried out in two steps. In step one, a descriptive test was conducted in a 10-person expert group to determine taste profile, sensory attributes and salinity level of the samples (Vidal et al., 2018). Experts were asked to write down any certain taste and aftertaste they recognize in the samples.

In step two, based on the results of the descriptive test, an intensity test Rata (rate-all-that-apply) was conducted. 30 consumers, willing to try the samples, aged 18 – 64 took part in the sensory evaluation. 80% were female, but 83% aged 18 – 25. Panellists were asked to distinguish any taste characteristics in the experimental dressing samples and rate the intensity in 1 (not intense) to 5 (very intense) scale (Meyners et al., 2016). Samples were marked with 3-digit numbers, served in a 30 ml transparent plastic container along with crisp bread pieces and water to cleanse the palate.

Dehydrated sauerkraut juice in bread and meat applications

Preparation of experimental bread samples

For the bread samples wheat flour "Kviešu milti Dobele ekstra" (Dobeles Dzirnavnieks, Latvia), a fine salt "Artiomsol" (Ukraine), sugar "Dansukker Jelgavas" (Nordic Sugar, Lithuania), yeast "Saf instant" (Lesaffre, France) was used and it was made according to the following formulation: 1% salt, 2% sugar, 3% yeast and 60% water added to the necessary amount of flour to knead a dough. All the ingredients were placed in a spiral type dough mixer KM400 (Kenwood Havant, Hampshire, UK) and kneaded for 7 minutes, let to rest for 10 minutes, formed in a baguette-like loaf, and proofed for 45 minutes in a proofing cabinet Sveba Dahlen (Sveba Dahlen AB, Fristadt, Sweden) at 35 ± 5 °C and 80% humidity. The loaves were then baked in a preheated rotary oven (Sveba Dahlen, Fristad, Sweden) at 200 ± 3°C for 17 minutes, and then cooled down to room temperature for further analysis. For the sample with DSJ – 1% NaCl and 2% of sugar were substituted with 10% of dehydrated sauerkraut juice.

Preparation of experimental meat samples

The minced pork meat was purchased from a local shop for the meat samples. The control sample was made using meat, and no salt or spices were added. For the experimental sample, 9% of dehydrated sauerkraut juice was added. For both samples, the meat was kneaded, formed into long, sausage-like loaves and then baked in the preheated rotary oven (Sveba Dahlen, Fristad, Sweden) at 200 ± 3°C for 15 minutes.

Samples and abbreviations

For further use in the text, abbreviations for the samples were made, and are described in Table 2.4.

For all of the bread and meat samples, total phenol content, antiradical activity, volatile compounds, sensory evaluation and simulated digestion *in vitro* was carried out.

Table 2.4. / *2.4. tabula*

The list of experimental bread and meat samples and abbreviations / *Maizes un gaļas paraugu apzīmējumi un lietotie saīsinājumi*

Sample / *Paraugs*	**Abbreviation /** *Saīsinājums*
Bread control sample / *Maizes paraugs, kontrole*	Bread C
Bread with dehydrated sauerkraut juice / *Maizes paraugs ar dehidrētu skābētu kāpostu sulu*	Bread DSJ
Meat control sample / *Gaļas paraugs, kontrole*	Meat C
Meat with dehydrated sauerkraut juice / *Gaļas paraugs ar dehidrētu skābētu kāpostu sulu*	Meat DSJ

Sensory evaluation

For the evaluation of bread and meat samples, a 5-point hedonic scale (1 – not particularly like and 5- like the most) for consumer preferences was used. Overall liking, structure, taste and aroma of the bread and meat samples were evaluated. 52 consumers, willing to try the samples, took part in the sensory evaluation. 38% of the consumers were 25 years old or older, and 17% were male. Consumers were allowed to taste the samples multiple times in order to distinguish the differences between the samples. Drinking water to cleanse the palate was offered to the participants.

2.4. Methods and standards for analytical parameters / *Analītisko parametru noteikšanas metodes un standarti*

For raw material – fresh cabbage and sauerkraut juice, and the obtained samples of concentrated (CSJ) and dehydrated (DSJ) sauerkraut juice, physical, chemical and microbiological analysis, shown in Table 2.5., were carried out.

Moisture content was determined gravimetrically, samples were dried (Universal Oven UF55, Memmert, Germany) at 105 ± 1 °C till constant weight according to standard ISO 939:2021.

Salt content was measured according to standard ISO 1738:2004, by titration as described in Mohr's method: determination of chloride, expressed as sodium chloride. Silver nitrate solution and potassium chromate as indicators were used (Deniz Korkmaz, 2012). To determine salt content in dehydrated sauerkraut juice, the dehydrant was diluted in deionized water and sodium chloride was calculated. For evaporated sauerkraut juice 5 mL of concentrate was titrated with $AgNO_3$ and sodium chloride was calculated.

Table 2.5. / *2.5. tabula*

Methods and standards for determination of analytical parameters / *Analītisko parametru noteikšanas metodes un standarti*

No. / *N.p.k.*	**Analytical parameters /** *Analītiskie parametri*	**Method or standard /** *Metode vai standarts*
Physicochemical parameters/ *Fizikāli ķīmiskie rādītāji*		
1.	Moisture / *Mitrums*	ISO 939:2021
2.	Salt content / *Sāls saturs*	Mohr's method
3.	Solubility in water / *Šķīdība ūdenī*	Jafari et al., 2017
4.	Total soluble solids / *Šķīstošā sausna*	ISO 2173:2003
5.	pH / *pH*	ISO 1842:1991
6.	Volatile compounds / *Gaistošie savienojumi*	Gas chromatography method (GC) / *Gāzes hromatogrāfijas metode*
7.	Vitamin C / *C vitamīns*	PB-135/HPLC ed. II of 15.09.2015
8.	Ascorbic acid / *Askorbīnskābe*	Seglina 2007
9.	Total phenol content / *Kopējie fenoli*	ISO 5983-1:2005/ Singleton
10.	DPPH• antiradical activity / *DPPH• antiradikālā aktivitāte*	Spectrophotometricaly (X. Liu et al., 2007) / *Spektrofotometriski*
11.	$ABTS^+$ Antiradical activity / *$ABTS^+$ antiradikālā aktivitāte*	Spectrophotometricaly (Re et al., 1999) / *Spektrofotometriski*
12.	Free phenolic compounds / *Brīvie fenolu savienojumi*	HPLC-ESI-TQ-MS
13.	Organic acids / *Organiskās skābes*	HPLC method / *AEŠH metode*

Continuation of table 2.5.
2.5. tabulas turpinājums

No. / *N.p.k.*	**Analytical parameters /** *Analītiskie parametri*	**Method or standard /** *Metode vai standarts*
12.	Protein (N*6,25) / *Olbaltumvielas*	PB - 116 ed. II 30.06.2014
13.	Dietary fiber / *Šķiedrvielas*	AOAC 991.43:1994
14.	Ash content / *Pelnvielas*	PN - A - 75101 - 08:1990 + Az 1:2002 /ISO2171: 2010
15.	Minerals / *Minerālvielas*	PB - 223 / ICP, ed. II 12.01.2015
16.	Fat content / *Tauku saturs*	PB - 286 ed. I 26.09.2014
17.	Sugars profile / C*ukuru profils*	Enzymatic - spectrophotometric/ *Enzimātiski - spektrofotometriski*
18.	Sodium / *Nātrijs*	PB-318/FAAS, ed. I of 27.07.2015
19.	Nitrates / *Nitrāti*	PN-A-75112:1992
Microbiological parameters / *Mikrobioloģiskie rādītāji*		
20.	Total plate count, CFU g^{-1} / *Mikroorganismu kopskaits, KVV* g^{-1}	ISO 4833-1:2013
21.	Lactic acid bacteria, CFU g^{-1} / *Pienskābes baktērijas KVV* g^{-1}	LVS ISO 15214 :1998
Energy value / *Enerģētiskā vērtība*		
22.	Energy value / *Enerģētiskā vērtība*	Regulation (EC) No. / 1169/2011 *ES Regula Nr. 1169/2011*
Sensory analyses / *Sensorā analīze*		
23.	5-point hedonic scale / *5-punktu hedoniskā skala*	ISO 11136:2014
24.	Characteristic methods / *Raksturojošās metodes*	ISO 4121:2003 ISO 8586:2012
Evaluation of bioaccessibility / *Biopieejamības izvērtēšana*		
25.	*In vitro* analyses / *Analizēšana in vitro apstākļos*	Minekus et.al.2014

Solubility in water for dehydrated sauerkraut juice was determined gravimetrically as described by Kuck & Noreña (2016) – 1 g of dehydrated sauerkraut juice was stirred (magnetic stirrer) with a 30 ml of deionized water for 30 min, then transferred into a centrifuge tube and centrifuged at 3500 rpm for 6 min 20 mL centrifuged solutions were transferred to a petri dish and dried at 105 ± 1 °C to a constant weight. The solubility was expressed as the initial weight minus the final weight, divided by the initial weight, as shown in equation 2.2.

$$\text{Solubility}(\%) = \frac{initial\ weight - final\ weight}{initial\ weight} \times 100 \qquad (2.2.)$$

Total soluble solids (°Brix) was measured using standard method ISO 2173: 003 on a digital refractometer Refracto 30GS (Mettler Toledo, Japan) with a measurement error ±0.1%. Refractometer is calibrated with deionized water before measurement.

pH was measured applying standard method LVS ISO 1842:1991on pH – metre Jenway 3510 (Baroworld Scientific Ltd, UK) with a measurement error of pH ± 0.001. The pH metre is calibrated with calibration solutions pH 7.00 and pH 4.00.

Volatile compounds. Volatile compounds were determined for sauerkraut juice, dehydrated sauerkraut juice, experimental dressing samples with olive oil and with sour cream, for bread and meat samples.

A solid-phase microextraction (SPME) technique was used (Galoburda et al., 2020) to determine volatile compounds. 5 g of sauerkraut juice, experimental dressing samples, bread and meat samples and 0.5 g of DSJ were were placed in a 20 mL glass vial, rubber sealed and closed with a cork, heated and stirred for 10 min at 35 ± 2°C to equilibrate headspace and 30 min with CarboxenTM/Polydimethylsiloxane (CAR/PDMS) fibre (Supelco Inc., Bellefonte, PA, USA) at 40 ± 2°C to extract volatiles. During this stage, the volatile compounds were absorbed on the fibre. The volatile compounds from the fibre were thermally desorbed in the GH/MS injector. The separation of volatiles was performed on an Elite-wax (PerkinElmer, Inc, USA) capillary column (60 m × 0.25 mm I.D., polyethylene glycol coating thickness 0.25 µm). GC-MS analyses was performed with the following parameters: initial temperature 40 ± 0.1°C, held for 7 min, then temperature was increased to 160 ± 0.1°C, with a rate of 6 ± 0.1°C min^{-1}, then it was increased to 210 ± 0.1°C at a rate of 10 ± 0.1°C min^{-1} and held at this temperature for 15 min The mass spectrometer in electron impact ionisation mode was set at 70 eV as the electron energy while the ion temperature was set to 250°C and the inlet temperature was sert to 250 ± 0.1°C. Injections were performed in split mode (2:1) and He (helium) was used as a carrier gas at a constant flow of 1 mL min-1; in full scan mode – m/z 40-300. Solid-phase microextraction (SPME) technique was used. The obtained compound data was identified using mass spectral library Nist98.

Total phenol content and **antiradical activity**. Determination of total phenol content has been done using widely applied spectrophotometric analyses proposed by Singleton et al. (1999). In addition, the antiradical activity of extracts obtained using solvent extraction with acidified aqueous ethanol solution was analysed according to the procedure described by Gouw et al. (2017).

Water extracts were prepared by stirring 1 g of dehydrated sauerkraut juice and 20 mL deionized water on a magnetic stirrer for 2 h as described in previous studies (Jansone et al., 2022).

Acidified ethanol extracts were prepared by mixing 2 g of DSJ and 30 mL of 60% ethanol acidified with 1% glacial acetic acid, extracted in ultrasonic water bath YJ5120-1 (Oubo Dental) at 35 KhZ, 20 ± 1 for 20 min, then centrifuged (Gouw et al., 2017).

For fresh cabbage, sauerkraut juice and concentrated sauerkraut juice, extracts were prepared as follows: 3.5 g minced fresh cabbage, 10 mL SJ, 5 g CSJ were added to 20 mL of ethanol/deionized water (80:20) and stirred on a magnetic stirrer for 2 h, then filtered. Total phenol content was determined as described by Singleton et.al. (Singleton et al., 1999) with some modifications. Briefly, to 0.5 mL sample extract 2.5 mL Folin – Ciocalteu reagent (diluted ten times with distilled water) was added. After 5 min, 2 mL 7.5% Na_2CO_3 was added and left at room temperature to react for 30 min The absorption was measured on a laboratory spectrophotometer JENWAY 6300 (Baroworld Scientific Ltd., UK.) at 765 nm. The results were then expressed by dry weight, GAE.

Determination of antiradical activity by DPPH•, a method described by Thaipong (2006) with modifications. Briefly 0.004 g of 2,2-diphenyl 1-picrylhydrazyl was diluted with 96% ethanol to reach the absorption of 1.000 ± 0.02 at 517 nm. 3.5 mL of this stock solution was then mixed with 0.5 mL of sample extract and left to react in the dark for 30 min The absorption was measured spectrophotometrically. Results are expressed as mg Trolox equivalent (TE) 100 g^{-1}, dry weight (Prieciņa & Kārkliņa, 2014).

Determination of antiradical activity by $ABTS^{+}$, a method described by Rokayya et.al (2013) with some modifications. For the stock solution 2,2´-azinobis-(3- ethylbenzothiazoline-

6 sulphonate) was diluted in phosphate buffered saline PBS then oxidised with potassium persulphate and left to react overnight. The absorption of 0.800±0.030 at 734 nm was set. A solution of 0.05 mL sample extract and 5 mL pre-prepared stock solution was mixed and left to react for 10 min, and absorption was measured spectrophotometrically. Results are expressed as mg Trolox equivalent (TE) 100 g^{-1}, dry weight (Kruma et al., 2016).

Extraction of free phenolics was done by either solid-liquid or liquid-liquid extraction according to the procedure described by Gonzales et al., (2014) with modifications. Briefly, 1 g of each sample in triplicate was placed in 15 mL conical centrifuge tubes (Sarstedt AG & Co. KG, Nümbrecht, Germany), and 5 mL acidified 100% MeOH (1.0% HCOOH v/v) was added. Then, the obtained mixture was subjected to 1 min intensive Vortexing using the "ZX3" vortex mixer (Velp® Scientifica, Usmate Velate, Italy), followed by centrifugation at 8700× g for 10 min at 4.0 ± 1 °C in a "Hermle Z 36 HK" centrifuge (Hermle Labortechnik, GmbH, Wehingen, Germany). After centrifugation, the top organic layer was separated and collected. Afterwards, the extraction procedure was repeated thrice using 80% acidified MeOH (1.0% HCOOH v/v) as an extraction solvent. Finally, the resulting fraction (15 mL) was evaporated using a "Laborota 4002" rotary evaporator (Heidolph, Swabia, Germany) at 45 °C. The dry residues were then reconstituted in 2 mL 80% acidified MeOH (1.0% HCOOH v/v) and filtered through a polytetrafluoroethylene hydrophobic (PTFE) membrane filter with a pore size of 0.20 µm. The HPLC-ESI-TQ-MS/MS analytical conditions for phenolics were carried out using a Shimadzu series Nexera UC SFC-SFE-LC system (Tokyo, Japan) coupled to TQ-MS-8050 (Tokyo, Japan) with an electrospray ionisation interface (ESI). All phenolics were observed in the programmed and optimised multiple reaction monitoring (MRM) mode.

Organic acids were conducted on a high-performance liquid chromatography (HPLC) "Shimadzu LC-20 Prominence" equipped with a UV/Vis detector (DAD SPD-M20A), pump system, gradients A - Acetonnitrile; B – 0.05M KH_2PO_4 monitored at 210 nm, column Alltech C18 (4.6 mm x 250 mm), flow rate 1.25 mL min^{-1}, at 35 °C (Tomsone et al., 2020; Jansone et al., 2022). Organic acids were calculated according to equation 2.3.

$$Organic\ acid = \frac{volume\ of\ sample\ \times concentration\ of\ acid}{mass\ of\ the\ sample} \times 100 \qquad (2.3.)$$

Ascorbic acid – for fresh and sauerkraut juices an iodometric titration method was used (Seglina, 2007; *College of Science Safety*). Briefly, 10 mL of juice was added to 100 mL 6% $H_2C_2O_4$ (oxalic acid) and mixed with a blender for 1 minute and then filtered. 2 mL of 1% starch solution was added to 10 mL of filtrate and titrated with 0.05 M iodine solution till the colour is persistent for 30 seconds. The results were calculated according to equation 2.3

$$Ascorbic\ acid = 5000 \times \frac{V\ sample}{m\ \times V\ standart} \qquad (2.4.)$$

Where: 5000 – coefficient;

V_{sample} – the amount of iodine solution used for the titration of 10 mL of the sample;

$V_{standard}$ – the amount of iodine solution used for the titration of 25 mL standard solution;

m – the amount of sample used;

For DSJ and CSJ, a HPLC method was applied.

For **microbiological analyses** samples of 1 g of dehydrated and 10 g of concentrated sauerkraut juice, 10 g of fresh and 10 g of sauerkraut juice were diluted in 90 mL sterile saline (0.85% NaCl) and homogenised with a stomacher (Bagmixer Interscience, Bois Arpents F.) for 1 min at speed 8 using internal filter bags (Jansone et al., 2021). For bacterial growth obtained filtrate was plated on Petri dishes with selected medium (Scharlau). The description and parameters are described in Table 2.6. Enumeration was carried out on an Acolyte 7510 colony counter (SYN, Synbiosis, England).

Table 2.6. / *2.6. tabula*

Microbiological test parameters / *Mikrobioloģisko analīžu parametri*

Parameter and agar / *Parametrs un barotne*	**Medium /** *Barotne*	**Reference number** / *References numurs*	**Incubation** / *Inkubācija*
Total plate count / *Kopējais mikroorganismu skaits*	**PCA** (Plate Count Agar)	01-161-500	30 °C; 48 h
Lactic acid bacteria / *Pienskābes baktērijas*	**MRS** agar	01-135-500	37 °C; 72 h

In vitro digestion method

A standardised static *in vitro* digestion method, described by Minekus (Minekus et al., 2014) was used in the study for the SJ, DSJ, bread and meat samples. It was performed in a model environment of the gastrointestinal tract (GIT) – a bio-reactor Multifors 2 (Infors-HT, Switzerland) in which digestibility and transit of digestive medium is simulated. The process is controlled by a computer program Iris 6 Parallel bioprocess Control Software (Infors-HT, Switzerland). 30 g of the sauerkraut juice, bread and meat samples and 1 g of DSJ were placed in the bioreactor with a pH and temperature control, simulated saliva fluid (SSF) is then added and kept for 2 minutes at 37 °C. The transition to the stomach is simulated by introducing the simulated gastric fluid (SGF), which consists of a concentrated electrolyte solution, the enzyme pepsin, $CaCl_2$ and deionized H_2O. Gastric acid secretion was simulated by adding 1 M HCl and adjusting pH to 3.0 ± 0.2. Digestibility in the stomach is simulated for 2 hours. Next the stomach content is neutralised to pH 7.0 ± 0.2 by adding 1 M $NaHCO_3$ and simulated intestinal fluid (SIF), which consists of a concentrated electrolyte solution, enzymes (trypsin, chymotrypsin, α-amylase, lipase), bile salts, $CaCl_2$ and deionized H_2O, thus simulating the transit to the duodenum. Digestibility in the small intestine was simulated for 2 hours. After the digestion process, the content is frozen to terminate the process of further hydrolysis.

The bioaccessibility index (BAC) was calculated using the following equation (Quatrin et al., 2020):

$$BAC = \frac{CAD}{CBD} \qquad (2.5.)$$

Where: CAD – the TPC and antiradical activity after gastrointestinal digestion;
CBD – the TPC and antiradical activity in the samples before digestion.

The bioaccessibility index was calculated for SJ, DSJ, bread and meat samples.

2.5. Statistical analyses / *Datu matemātiskā apstrāde*

The results are shown as the mean value ± standard deviation. Significant differences are considered as significant at $p<0.05$ among the acquired samples and were determined by a t-test when two samples were compared in the sensory tests. Analysis of variance (ANOVA) and Tukey’s test is used to evaluate the effect of tested factors and to determine differences among the samples. Cluster analyses and heat maps were used for evaluation of concentration methods. Correlation analyses were performed to evaluate relationships between parameters. Figures and tables were created and the obtained data was calculated on MS Excel for Windows 2019 software.

3. RESULTS AND DISCUSSION / *REZULTĀTI UN DISKUSIJA*

The results section summarises the results during the experiments and provides a scientific discussion.

3.1. Fresh cabbage and sauerkraut juice characteristics / *Svaigu un skābētu kāpostu sulas raksturojums*

The analyses of physicochemical properties of fresh cabbage heads were carried out in three periods of time – December 2018; November 2020 and April 2021 for two varieties 'Selma' and 'Kiloplons' and in December 2018 for the variety 'Ramkila'. The varieties for the project were selected based on their quality and agrotechnical condition, and a decision was made not to continue growing the 'Ramkila' variety, therefore no further studies are being conducted. The objective of obtaining the following results was to gather initial data on fresh cabbage for the purpose of comparison with sauerkraut juice and the resulting products. The detailed results in this section are presented from the year 2018, and the dispersion of results compiled (Figure 3.2. and 3.3.) from the mentioned three periods of time (2018 – 2020) when the cabbage was delivered.

Organoleptic differences were noticed among the varieties. 'Selma' was with firm, large (5 – 6 kg) and pale green heads. 'Kiloplons' was lighter (3-4 kg), not so firm, green head, while 'Ramkila' (5-6 kg) had almost white, very firm head. Though 'Ramkila' had spoiled leaves from outside and within, as seen in Fig. 3.1., which caused significant losses in the production.

A B C

Fig. 3.1. **Cabbage variety 'Selma' (A), 'Kiloplons' (B) and 'Ramkila' (C) heads /** *3.1. att. Šķirnes 'Selma' (A), 'Kiloplons' (B) un 'Ramkila' (C) kāposti*

The images are taken after the harvest 2018, at the time of delivery to Latvia University of Life Sciences and Technologies for analyses / *Fotogrāfijas tika uzņemtas 2018. gadā pēc ražas novākšanas un kāpostgalviņu piegādes uz Latvijas Biozinātņu un Tehnoloģiju Universitāti turpmākām analīzēm*

The chemical composition of fresh cabbage juice varied among tested varieties. The biotic and abiotic conditions can explain the main differences between selected varieties during the vegetation period that influenced the accumulation of antioxidants and other compounds involved in regulating the metabolic activity of cabbage. In particular, the phenolic compounds with hydroxyl groups ensure antioxidant activity against environmental stress factors (Thakur et al., 2017; Kovalikova et al., 2019). In the Table 3.1. analyses of fresh cabbage and cabbage juice, harvested in 2018, are presented.

White cabbage is known to be a rich source of ascorbic acid and can provide the daily requirements for vitamin C: 75 – 90[8] mg (Zhao et al., 2020).

[8] Vitamin C, average daily recommended amounts [online] [viewed on 21. January 2023]. Retrieved from https://ods.od.nih.gov/factsheets/VitaminC-Consumer/

Table 3.1. / *3.1. tabula*

Ascorbic acid and total phenol content in fresh cabbage and fresh cabbage juice, harvest year 2018 /

Askorbīnskābes un kopējo fenolu saturs svaigos kāpostos un kāpostu sulā, 2018. ražas gads

	Parameters/ *Rādītāji*, **mg 100 g⁻¹ DW**			
	Ascorbic acid / *Askorbīnskābe*		**Total phenol content/** *Kopējais fenolu saturs*	
Cabbage variety/ *Kāpostu šķirne*	**Fresh cabbage/** *Svaigi kāposti*	**Fresh cabbage juice** / *Svaigu kāpostu sula*	**Fresh cabbage/** *Svaigi kāposti*	**Fresh cabbage juice/** *Svaigu kāpostu sula*
‘Selma’	579.32 ± 11.21bA	809.71 ± 5.33aA	305.07 ± 11.43bB	1900.00 ± 13.26aA
‘Kiloplons’	546.77 ± 10.82aB	522.62 ± 3.51bB	325.88 ± 16.51bB	1314.17 ± 10.02aB
‘Ramkila’	493.11 ± 13.14bC	511.78 ± 3.14aB	385.36 ± 10.69bA	1278.69 ± 11.94aB

*DW – dry weight/ *sausna*

Different lowercase letters show significant ($p<0.05$) differences between fresh cabbage juice and fresh cabbage (t-test), whereas upper case letters show significant differences between varieties (ANOVA) / *Dažādi mazie burti uzrāda būtiskas (p<0,05) atšķirības starp svaigo kāpostu sulu un svaigiem kāpostiem (t-tests), bet lielie burti uzrāda būtiskas atšķirības starp šķirnēm (ANOVA)*

The highest content of ascorbic acid was determined in the variety ‘Selma’ cabbages and cabbage juice. Our experimental results regarding vitamin C content are consistent with those reported by Zhao, Kovalikova etc. (2019; 2020). Specifically, our results, expressed as ascorbic acid content per fresh weight, fell within the range of 31 to 49 mg 100 g $^{-1}$. According to USDA[9] nutrient database the standard amount of vitamin C in white cabbage is 36,6 mg 100 g^{-1}. There is a variation in ascorbic acid content studied previously by different authors, ranging from as low as 9 to 80 mg 100 g $^{-1}$ FW (Park et al., 2014; Xu et al., 2020; Zhao et al., 2020). All the various factors mentioned before (Fig.1.1.) influence ascorbic acid content – abiotic conditions, cultivar, soil, maturity (Park et al., 2014), climate controlled or conventional storage etc. There can even be variations of ascorbic acid content in different leaf layers of one head, decreasing towards inner layers, and is variety and climatic conditions dependant, as investigated by Zhao and colleagues (2020a). The content of ascorbic acid also increased in the outer leaves of white cabbage, that were exposed to biotic stress caused by insect attack, as well as increased enzyme activity in the wounded areas (Kovalikova et al., 2019). So, the more outer cabbage leaves are taken away, the less vitamin C and antioxidants there will be left in the cabbage head (Zhao et al., 2020a).

According to obtained data, it is seen that the concentration of TPC in the extracts obtained from fresh cabbage varied in the range from 305.07 to 385.36 mg 100 g^{-1} DW, with variety ‘Selma’ having the lowest value and variety ‘Ramkila’ the highest.

It has been reported that plants exposed to environmental biotic and abiotic stress factors such as extreme temperatures, UV radiation, drought, etc., demonstrate relatively higher content of phenolic compounds. The primer function of phenolics is to protect plants against these factors by scavenging free radicals such as reactive oxygen (ROS) and nitrogen (RNS) species (Chowdhary et al., 2021).

According to those mentioned above, it is assumed that cabbage of the variety ‘Ramkila’ was exposed to some of such factors during growing or postharvest handling that perhaps triggered synthesis and the accumulation of phenolic. However, opposite results on TPC were

[9] FoodData Central, cabbage raw [online] [viewed on 1. June 2022]. Retrieved from https://fdc.nal.usda.gov/fdc-app.html#/food-details/169975/nutrients

obtained for extracts recovered from fresh cabbage juice. The highest concentration of TPC was found in the cabbage variety 'Selma', while the lowest was in 'Ramkila' (Cvetković et al., 2019; Kovalikova et al., 2019; Zhao et al., 2020). Paramithiotis et al., observed that TPC in fermented vegetables was higher in the juice compared to that in the pulp portion (2022). Scientists agree that stressed plants express more antioxidant activity and produce phenolic compounds to grow resistance against external conditions, like insects, for example (Kovalikova et al., 2019).

Antiradical activity by DPPH• assay is not significantly different ($p > 0.05$) between tested varieties, but significantly higher activity ($p < 0.05$) was observed in fresh cabbage juice (Table 3.2.). However, opposite results were obtained regarding $ABTS^+$ values, where statistically higher antiradical activity was observed in the extracts recovered from fresh cabbage, in particular the variety 'Ramkila'while the lowest for 'Selma'. Observed $ABTS^+$ values strongly correlate ($r = 0.95$) with TPC values indicating a relationship between phenolic compounds and antiradical scavenging activity. Relatively lower values obtained using the DPPH• method imply its less effectiveness in estimating the antiradical activity of aqueous extracts rich in polar compounds such as phenolics. The advantage of DPPH• radical scavenging activity has been widely documented for hydrophobic systems such as fat-soluble vitamins (tocopherols, tocotrienols), fatty acids, and sterols (Balciunaitiene et al., 2022).

Table 3.2. / *3.2. tabula*

Antiradical activity in fresh cabbage and its juice, 2018 harvest year /
Antiradikālā aktivitāte svaigos kāpostos un to sulā, 2018. ražas gadā

	Parameters/ *Rādītāji*, **mg TE 100 g⁻¹ DW**			
	Antiradical activity by DPPH•/ *Antiradikālā aktivitāte*		**Antiradical activity by ABTS⁺/** *Antiradikālā aktivitāte*	
Cabbage variety/ *Kāpostu šķirne*	**Fresh cabbage/** *Svaigi kāposti*	**Fresh cabbage juice/** *Svaigu kāpostu sula*	**Fresh cabbage/** *Svaigi kāposti*	**Fresh cabbage juice/** *Svaigu kāpostu sula*
'Selma'	25.06 ± 2.01bA	48.33 ± 1.72aA	96.75 ± 7.39aA	25.46 ± 1.88bA
'Kiloplons'	24.26 ± 1.53bA	49.26 ±3.61aA	100.69 ± 8.91aAB	18.24 ± 0.93bB
'Ramkila'	25.74 ± 2.17bA	47.99 ± 1.29aA	116.44 ± 9.18aA	18.26 ± 1.06bB

*DW – dry weight/ *sausna*

Different lowercase letters show significant ($p < 0.05$) differences between fresh cabbage juice and fresh cabbage (t-test), whereas upper case letters show significant differences between varieties (ANOVA) */ Dažādi mazie burti uzrāda būtiskas (p<0,05) atšķirības starp svaigo kāpostu sulu un svaigiem kāpostiem (t-tests), bet lielie burti uzrāda būtiskas atšķirības starp šķirnēm (ANOVA)*

Antiradical activity determined by DPPH• method in fresh cabbage juice had no statistically significant differences ($p > 0.05$) among varieties. Zhao et al. have investigated that antioxidant content in the cabbage heads decreases from the outer leaves, that posse's stronger antioxidant activity, towards the core and can decrease up to 70% of the capacity (Zhao et al., 2020).

There is a great variation in bioactive compounds that is dependent on the variety of white cabbage, time of harvest and storage, as shown in Figure 3.2.

Ascorbic acid is highly influenced by all the factors mentioned before – variety, climatic conditions, insects, maturity stage, postharvest handling and processing.

There is a great variation in the results of our study, that could be influenced by a set of circumstances. The maximum and minimum amount of ascorbic acid was in the variety 'Selma'. In November 2020 corresponding to 2746 mg 100 g^{-1}, and, the minimum – 267 mg 100 g^{-1}, was in April 2021. Since the range of the data is very vast, the median of the variety 'Selma' is 808 and 'Kiloplons' 526 mg 100 g^{-1}.

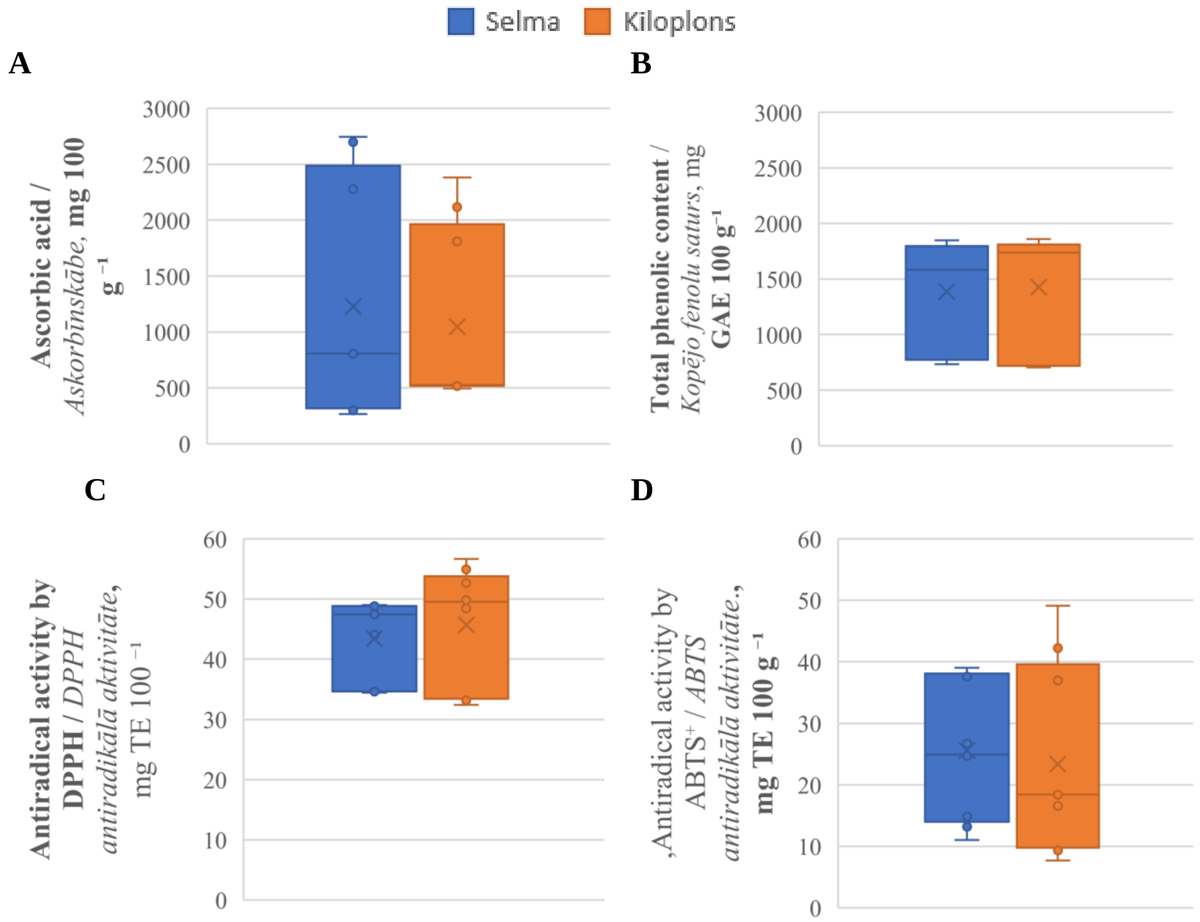

Fig. 3.2. **Variation of the results of ascorbic acid, TPC and antiradical activity in fresh cabbage juice in harvesting years 2018 – 2020** /*3.2.att. Askorbīnskābes, kopējo fenolu un antiradikālās aktivitātes rezultātu izkliede svaigu kāpostu sulā no 2018. – 2020. ražas gadam*
A – Ascorbic acid / *Askorbīnskābe;* **B – Total phenol content** / *Kopējo fenolu saturs;* **C- Antiradical activity by DPPH• /** *DPPH• antiradikālā aktivitāte;* **D - Antiradical activity by ABTS$^+$** / *ABTS$^+$ antiradikālā aktivitāte*

White cabbage is also an objective of investigation due to abundance in phenolic compounds. And again, the characteristics and amount of the phenolic compounds is influenced by many factors (Aires et al., 2011; Šamec et al., 2017) as described before (Fig.1.1.). The TPC results in our study are similar to ascorbic acid. The maximum and minimum of TPC was in the variety 'Selma' in December 2018 corresponding to 1936 mg GAE 100 g^{-1} and 578 mg GAE 100 g^{-1} in April 2021. The median is 1627 and 1301 mg GAE 100 g^{-1} for 'Selma' and 'Kiloplons', respectively. The TPC, according to previous studies by different scientists fluctuates from 8.7 to 153.3 mg GAE 100 g^{-1} FW (Aires et al., 2011; Moreb et al., 2020) and is in the range of our findings as seen in Figure 3.2.B.

There are no significant median differences ($p>0.05$) between varieties and the time of analyses in antiradical activity by DPPH•, however, there is a great variation in the obtained results by ABTS$^+$. The highest and also the least activity was for the variety 'Kiloplons' – 49 and 8 mg TE 100 g^{-1} accordingly.

<u>Characteristics of sauerkraut juice</u>

The enzymes produced by microorganisms lead to the conversion of complex organic compounds such as sugars, present in fresh cabbage, into simpler compounds which is accompanied by the formation of a unique tangy taste typical for sauerkraut. The fermentation process results in improved organoleptic and nutritional quality that makes sauerkraut different from raw cabbage (Drašković Berger et al., 2020). The physiological properties of cabbage tissue can be affected by processing parameters, which can result in the accumulation of secondary metabolites such as phenolic compounds. This may be a contributing factor to the initial increase in antioxidant activity observed in cabbage samples during the fermentation process (Drašković Berger et al., 2020). Yet there are scarce reports done so far on how characteristics of raw material (cabbage) affect sensory and chemical composition on sauerkraut (Thakur et al., 2017; Satora et al., 2021).

Results show significant variation among the years, not significant among varieties. As well as variation among ascorbic acid content in fresh and fermented cabbage, and the % of growth or loss in the fermentation process is shown in Table 3.3 and 3.4.

Variations of ascorbic acid content are variety dependent due to chemical compound enzymatic reactions as described by Wagner and Rimbach (2009). However, Thakur et.al. (2017), have investigated that ascorbic acid increases till day 21 in the fermentation process, after that it gradually decreases and is not influenced by variety.

Table 3.3. / *3.3. tabula*

Ascorbic acid and total phenol content in sauerkraut juice, harvest year 2018 /
Askorbīnskābes un kopējo fenolu saturs skābētu kāpostu sulā, 2018. ražas gadā

Cabbage variety / *Kāpostu šķirne*	**Parameters /** *Rādītāji*, **mg 100 g⁻¹ DW**			
	Ascorbic acid / *Askorbīnskābe*	**%***	**Total phenol content /** *Kopējais fenolu saturs*	**%**
'Selma'	672.39 ± 15.51a	↓17%	1814.72 ± 8.33b	↓4%
'Kiloplons'	670.99 ± 8.12a	↑28%	1781.56 ± 6.11c	↑ 36%
'Ramkila'	591.87 ± 5.51b	↑16%	2002.87 ± 13.43a	↑57%

Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem, norāda būtiskas atšķirības*, ($p<0.05$).
* Differences in percentages for tested parameters between fresh cabbage juice and sauerkraut juice / *Pārbaudīto parametru procentuālās atšķirības starp svaigu un skābētu kāpostu sulu*

It is also observed by Draškovic et.al. (2020) that the fermentation process itself may increase ascorbic acid content, though after the fermentation process the loss of ascorbic acid may reach 40%. Ascorbic acid content in sauerkraut juice is variety and climatic conditions dependant.

The rise in ascorbic acid levels can be attributed to two factors: firstly, the activity of microorganisms during the fermentation process and secondly, the breakdown of the antioxidant compound ascorbigen in an acidic environment (Drašković Berger et al., 2020).

Table 3.4. / *3.4. tabula*

Antiradical activity in sauerkraut juice, 2018 harvest year/
Antiradikālā aktivitāte skābētu kāpostu sulā, 2018. ražas gadā

Cabbage variety/ *Kāpostu šķirne*	**Parameters/** *Rādītāji*, **mg TE 100 g⁻¹ DW**			
	DPPH•*	**%****	**ABTS**	**%**
'Selma'	94.77 ± 7.41a	↑96%	6.59 ± 0.70b	↓74%
'Kiloplons'	74.36 ± 6.42b	↑51%	11.36 ± 0.92a	↓38%
'Ramkila'	69.34 ± 4.08b	↑44%	7.18 ± 0.53b	↓61%

Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem, norāda būtiskas atšķirības* ($p<0.05$)
** Differences in percentages for tested parameters between fresh cabbage juice and sauerkraut juice / Pārbaudīto parametru procentuālās atšķirības starp svaigu un skābētu kāpostu sulu

Ciska and colleagues (2005) have investigated that the fermentation process increases TPC compared to fresh cabbage. Lactic acid fermentation can elevate the TPC (total phenolic content) of raw materials by either causing the breakdown of the cell wall of plant cells, which allows for their release from the vacuole where they are primarily located, or by enzymatically converting their glycosides into their aglycone form (Paramithiotis et al., 2022; Tlais, Lemos Junior, et al., 2022). However, Hallman et.al., (2017b) in their studies have come across quite the opposite observation – that the lactic acid fermentation decreases the total polyphenol content in the final product – sauerkraut. The process depends on the composition of LAB microbiome (Tlais, Kanwal, et al., 2022). Also, as Kusznierewicz et al. (2008) have come to the conclusion that antiradical activity initially increases during wounding or shredding, when preparing spontaneously fermented sauerkraut. However, metabolic pathways of biosynthesis or degradation of phenolic compounds by lactic acid bacteria have not been completely described (Rodríguez et al., 2009). The results, shown in Figure 3.3. are consistent with those available in the literature, indicating that the content of TPC is many factors-dependent and that the fermentation can contribute either to the reduction or increase of their content (Özer & Kalkan Yıldırım, 2019).

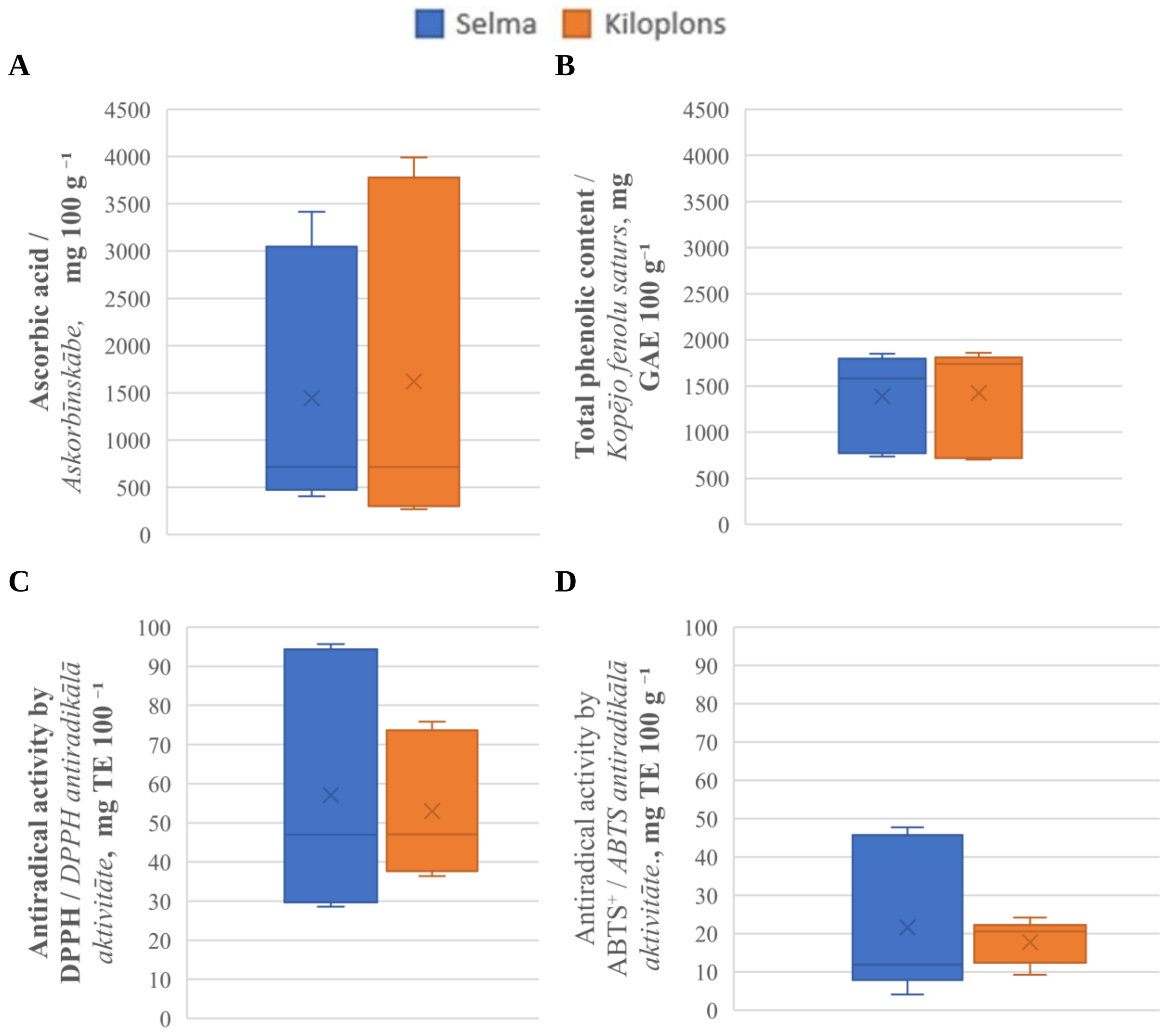

Fig. 3.3. **Variation of the results of ascorbic acid, TPC and antiradical activity in sauerkraut juice in harvesting years 2018 - 2020**

3.3. att. Askorbīnskābes, kopējo fenolu un antiradikālās aktivitātes rezultātu izkliede skābētu kāpostu sulā no 2018. – 2020. ražas gadam

A – Ascorbic acid / *Askorbīnskābe*; **B – Total phenol content** / *Kopējo fenolu saturs*; **C – Antiradical activity by DPPH•** / *DPPH• antiradikālā aktivitāte;* **D - Antiradical activity by $ABTS^+$** / *$ABTS^+$ antiradikālā aktivitāte*

There is a great variation in ascorbic acid content in sauerkraut juice, just like in the fresh cabbage. The minimum and maximum values, comparing the two varieties, is in variety 'Kiloplons' and is 269.1 mg 100 g^{-1} in April 2021 and 3991.25 mg 100 g^{-1} in November 2020, accordingly. However, the median (a dash in graphic bars) for ascorbic acid content in both varieties 'Selma' and 'Kiloplons' is absolutely the same and is 715 mg 100 g^{-1}. Also, the TPC minimum and maximum is in variety 'Kiloplons', the minimum is in April 2021 and is 704.4 and maximum in December 2018 – 1860.07 mg GAE 100 g^{-1} and there were significant differences in median – 1583.45 and 1739.35 mg GAE 100 g^{-1} for 'Selma' and 'Kiloplons' respectively. Most of the studies in literature are done on sauerkraut but very little on sauerkraut juice. TPC in sauerkraut varies from 108.7 – 438.3 mg GAE 100 g $^{-1}$, FW (Özer & Kalkan Yıldırım, 2019). Hallman et.al., (2017a) is one of the few that has investigated sauerkraut juice, particularly a study on fertilisation effect on fresh cabbage and sauerkraut chemical composition. Obtained results on total polyphenol content vary from 5.39 to 9.05 mg GAE 100 g $^{-1}$, FW, (different years, different cultivation systems – organic and conventional). Hallman also have found out that the highest polyphenol content was in the control sample without any fertilisation. Farmers have reported that during dry summers, fertilisation may not be as efficient, which could be one possible explanation for why the total plate count was highest in 2018, a year characterised by a very dry summer, according to our study.

Antiradical activity in sauerkraut is also greatly influenced by many factors, such as temperature, pH, fermentation time and process, as well as the solvent used for extraction (Özer & Kalkan Yıldırım, 2019). Zhao et.al., (2020) found that the outer leaves of cabbage exhibit stronger antiradical activity by $ABTS^+$ compared to the inner leaves, indicating a variation in antioxidant potential within the vegetable. Antiradical activity done by ABTS $^+$ and DPPH• methods is shown in Figure 3.3.C; D. However, Kusznierewicz and colleagues have come to conclusion that fermentation process does not always increase antiradical activity and ascorbic acid content (Kusznierewicz, Śmiechowska, et al., 2008) that agrees with our findings. On the other hand, Hallmann states that chemical and physical processes in the production of sauerkraut results in higher antiradical activity (Hallmann et al., 2017a). As Ōzer et al., (2019) in his study concludes, that in the initial phases of fermentation, the antioxidant activity in various fermented cabbage products saw an increase, but as the process progressed, it eventually decreased. These results are consistent with the impact of fermentation duration on antioxidant activity. According to the results obtained (Fig. 3.3.), there was no statistically significant difference between the median DPPH• antiradical activity values of the two varieties. However, significantly higher antiradical activity was observed in fermented cabbage harvested in 2018. Perhaps dry and warm summers were the main factors influencing the accumulation of bioactive compounds responsible for the radical scavenging activity.

In total, there were 13 profiles of free polyphenols represented in an industrial sample of sauerkraut juice, as shown in Fig 3.4., extracted ion chromatogram (EIC) in MRM mode.

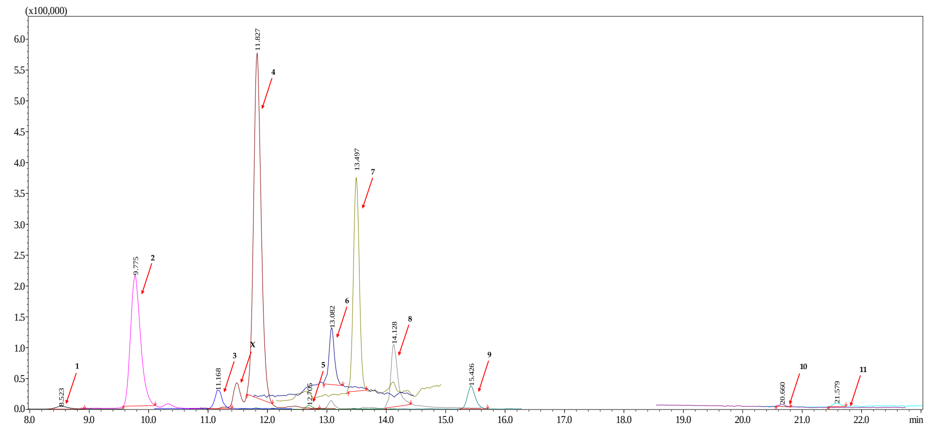

Fig. 3.4. **Free polyphenol profile in industrial sample of sauerkraut juice /**
3.4. att. Brīvie polifenolu savienojumi rūpnieciskā parauga skābētu kāpostu sulā

The highest peak areas were for neochlorogenic acid, chlorogenic acid, vanillin and caffeic acid, but also gallic acid, protocatechinic acid, syringic acid, sinapic acid, luteolin, O-glucoside, quercetin and rhamnetin. The obtained results are consistent with the literature, however, the studies agree that there are many factors that impact the structure and properties of polyphenols in white cabbage and sauerkraut (Peñas et al., 2017b; Šamec & Salopek-Sondi, 2019; Ciska et al., 2021).

As the study showed significant variation in the obtained results, an energy value and chemical composition of an industrial sample of sauerkraut juice, harvest year 2019, was determined and is shown in Table 3.5. It confirms the low value of calories, protein, fat and moderate amount of minerals and sugars.

Table 3.5. / *3.5. tabula*

Energy value and chemical composition of sauerkraut juice industrial sample, FW harvest year 2019 /

Skābētu kāpostu sulas enrģētiskā vērtība un ķīmiskais sastāvs, rūpnieciskais paraugs, 2019. ražas gads

Parameters / *Parametri*	**Unit /** *Mērvienība*	**Nutritional value /** *Uzturvērtība*, **100 g**
Energy value / *Enerģētiskā vērtība*	**kcal**	6
Carbohydrates / *Ogļhidrāti*	**g**	1.1
- including sugars */ ieskaitot cukurus*	**g**	0.6
Glucose / *Glikoze*	**g**	0.4
Fructose / *Fruktoze*	**g**	< 0.2
Maltose / *Maltoze*	**g**	< 0.2
Galactose / *Galaktoze*	**g**	< 0.2
- dietary fibre / *škiedrvielas*	**g**	< 0.5
Protein / *Olbaltumvielas*	**g**	0.4
Fat / *Tauki*	**g**	<0.1
Ash / *Pelnvielas*	**g**	1.02
Salt / *Sāls*	**g**	0.75
Minerals / *Minerālvielas*		
Magnesium / *Magnijs*	**mg**	0.088
Copper / *Varš*	**mg**	0.0025
Potassium / *Kālijs*	**mg**	91.2
Calcium / *Kalcijs*	**mg**	17.3
Iron / *Dzelzs*	**mg**	0.098
Nitrates / *Nitrāti*		
Nitrates as $NaNO_3$	**mg**	15.8
Nitrates as NO_3^-	**mg**	11.5

Sauerkraut juice may not always be a source of lactic acid bacteria, as seen in our results, Figure 3.5. It depends on variety and carbohydrate content in the cabbage head itself. LAB, along with other microorganisms present in sauerkraut, utilise the reduced sugars found in sauerkraut to fuel their own growth and reproduction during metabolism (Y. Liu et al., 2023).

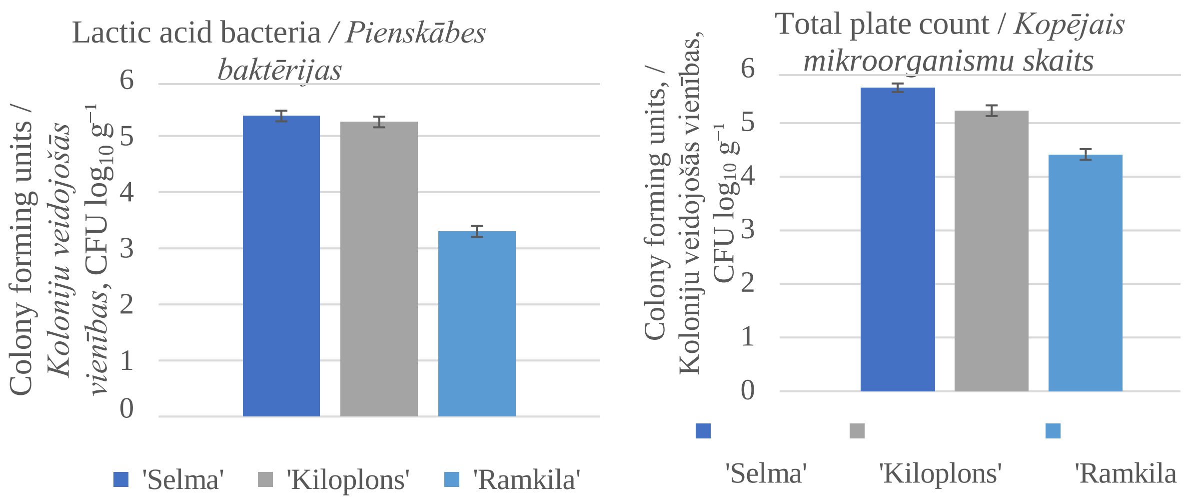

Fig. 3.5. **Lactic acid bacteria and total plate count in sauerkraut juice /**
3.5. att. Pienskābes baktēriju un kopējais mikroorganismu skaits skābētu kāpostu sulā

The highest CFU for LAB and total plate count were detected in variety ‘Selma’ 2.3 × 10^5 CFU g^{-1} and ‘Kiloplons’ 1.8 × 10^5 CFU g^{-1}, in comparison to variety ‘Ramkila’ 0.2 × 10^4 CFU g^{-1}, where the count was significantly reduced. There are diverse observations in literature, for the variety ‘Varadžin’, the LAB count reached 9.0 × 10^5 cfu ml^{-1} on 18^{th} day of fermentation (Beganović et al., 2014). However, for varieties ‘Storema’ and ‘Lennox’, the highest count of 2.2 × 10^8 CFU g^{-1} was on day 5 and maintained high till the 9^{th} day of fermentation (Palani et al., 2016). But declined to 1.4 × 10^3 CFU count after 56 days of storage. FAO[10] stipulates that for a product to be considered beneficial for health, it must contain at least 10^6 CFU g^{-1} viable probiotic cells in the product throughout its shelf-life and can withstand the harsh environment of the stomach.

Summary of Chapter 3.1. / *3.1. Nodaļas kopsavilkums*

The results of the physicochemical properties of fresh cabbage juice and sauerkraut juice of three varieties (‘Selma,’ ‘Kiloplons,’ un ‘Ramkila’) were obtained in three periods of time - from December 2018 till April 2021. In harvest year 2018, ‘Selma’ cabbage had the highest concentration of ascorbic acid, total phenol content and antiradical activity measured by DPPH assay in fresh cabbage juice. However, the same indicators were the lowest in April 2021, harvest year 2020.

Variations in ascorbic acid content in fresh and fermented cabbage are variety-dependent, and the fermentation process itself may increase ascorbic acid content, but the loss of ascorbic acid after fermentation can reach 40%.

The study found that there is a large variation in ascorbic acid and total phenol content in sauerkraut juice, with the highest values observed in November 2020 and December 2018. The study also found that there was no statistically significant difference in the antiradical activity of two different varieties of sauerkraut juice, but significantly higher antiradical activity was observed in sauerkraut, produced by cabbage harvested in 2018.

The highest lactic acid bacteria and total plate count were detected in varieties ‘Selma’ and ‘Kiloplons’.

Trīs šķirņu (‘Selma,’ ‘Kiloplons,’ un ‘Ramkila’) svaigu un skābētu kāpostu sulas fizikāli ķīmisko īpašību rezultāti iegūti trīs laika periodos - no 2018. gada decembra līdz 2021. gada aprīlim. 2018. ražas gadā, šķirnes ‘Selma’ svaigu kāpostu sulā bija vislielākā askorbīnskābes

[10] Probiotics in food, Health and nutritional properties [online] [viewed on 8.06.2022] Retrieved from https://www.fao.org/3/a0512e/a0512e.pdf

koncentrācija, kopējo fenolu saturs un DPPH antiradikālā aktivitāte. Tomēr tie paši rādītāji bija viszemākie 2020. gada ražai, analizēti 2021. gada aprīlī.

Šķirne ietekmē askorbīnskābes satura variācijas svaigos un skābētos kāpostos, un fermentācijas process var to palielināt, bet arī askorbīnskābes zudumi pēc fermentācijas var sasniegt 40%. Pētījumā tika konstatēts, ka askorbīnskābes un kopējo fenolu saturs skābētu kāpostu sulā ir ļoti mainīgs, un visaugstākie rādītāji tika novēroti attiecīgi 2020. gada novembrī un 2018. gada decembrī. Pētījumā arī konstatēts, ka nav statistiski nozīmīgas atšķirības antiradikālajā aktivitātē divu dažādu šķirņu skābētu kāpostu sulās, bet ievērojami lielāka antiradikālā aktivitāte novērota 2018. gada ražas skābētajos kāpostos.

Augstākais pienskābes baktērijas un kopējais mikroorganismu skaits konstatēts šķirnēm 'Selma' un 'Kiloplons'.

3.2. Comparison of concentrated sauerkraut juice technologies / *Koncentrētas skābētu kāpostu sulas ieguves tehnoloģiju salīdzinājums*

There were three evaporation techniques applied in experimental work to obtain concentrated sauerkraut juice (CSJ), namely – rotary vacuum evaporation (R), falling film evaporation (FF) and open kettle evaporation (OD).

3.2.1. Concentrated sauerkraut juice via rotary vacuum evaporation / *Rotācijas vakuuma ietvaicē koncentrēta skābētu kāpostu sula*

Freshly collected sauerkraut juice, from three different varieties, was concentrated on rotary vacuum evaporator, in January 2020, to obtain strongly flavoured concentrate. Overall characteristics of fermented and evaporated sauerkraut juice is shown in Table 3.6.

TSS in sauerkraut juice ranged from 7.66 to 9.58 °Brix with the highest value in the variety 'Kiloplons' sauerkraut juice, and also salt content was the highest in that sample. Concentration resulted in reduction of moisture and final TSS was from 28.52 to 32.14 °Brix. The highest TSS was in the variety 'Ramkila' concentrated sauerkraut juice (CSJ), and it also explains the highest salt content.

Table 3.6. / *3.6. tabula*

Characteristics of sauerkraut juice and concentrated sauerkraut juice via rotary vacuum evaporator, harvest year 2019 / *Skābētu kāpostu sulas un rotācijas vakuuma iekārtā koncentrātas skābētu kāpostu sulas raksturojums, 2019. ražas gads*

Variety / *Šķirne*	**Sample /** *Paraugs*	**TSS, ° Brix /** *Šķīstošā sausna*	**Sodium chloride, %** *Nātrija hlorīds*	**pH**	**Titratable acid content /** *Titrejamo skābju saturs,* **g 100 g⁻¹**
'Selma'	Juice	8.06 ± 0.25d	1.76 ± 0.08e	3.75 ± 0.01a	1.04 ± 0.02c
	CSJ*	29.52 ± 0.52b	3.82 ± 0.39c	3.74 ± 0.01a	3.44 ± 0.01a
'Kiloplons'	Juice	9.58 ± 0.41c	2.52 ±0.01d	3.74 ± 0.01a	1.06 ± 0.01c
	CSJ	28.52 ± 0.71b	4.42 ± 0.05b	3.71 ± 0.00a	3.13 ± 0.15b
'Ramkila'	Juice	7.66 ± 0.31d	1.72 ± 0.03e	3.72 ± 0.01a	0.92 ± 0.02d
	CSJ	32.14 ± 0.82a	5.02 ± 0.02a	3.63 ± 0.01b	3.32 ± 0.12ab

Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem, norāda būtiskas atšķirības* ($p \leq 0.05$).

*CSJ – concentrated sauerkraut juice / *koncentrēta skābētu kāpostu sula*

For tested samples during production added salt concentration was 1.7%, and results showed their distribution proportionally between juice and cabbages. Yang et al. (2023), have investigated the mass transfer kinetics in Kimchi during osmotic dehydration and states that white/hard and leafy parts, as well as moisture and soluble solids content impact the dispersion of salt in the final product. pH differences were insignificant, except the variety 'Ramkila' CSJ has lower pH. Significant differences for titratable acidity was determined only between the varieties 'Selma' and 'Kiloplons' CSJ.

TPC, antiradical activity of CSJ and changes during concentration process are presented in Table 3.7. The highest TPC and antiradical activity by DPPH• was determined in the variety 'Selma' CSJ. During concentration, significant ($p<0.05$) decreases of TPC were determined only in variety 'Kilaplons' CSJ.

Table 3.7. / *3.7. tabula*

Changes in TPC and antiradical activity in concentrated sauerkraut juice via rotary vacuum evaporator, harvest year 2019 / *Kopējo fenolu satura un antiradikālās aktivitātes izmaiņas rotācijas vakuuma iekārtā koncentrētā skābētu kāpostu sulā, 2019. ražas gadā*

Cabbage variety/ *Kāpostu šķirne*	**Parameters/** *Rādītāji*, **mg TE 100 g⁻¹ DW**					
	Total phenol content/ *Kopējais fenolu saturs*	**%***	**DPPH•**	**%**	**ABTS**	**%**
'Selma'	290.38 ± 11.10a	n.s.**	17.50 ± 0.22a	↑11%	39.74 ± 4.79a	↑12%
'Kiloplons'	246.06 ± 12.34b	↓15%	16.49 ± 0.32b	↑10%	37.03 ± 2.23a	↑14%
'Ramkila'	207.81 ± 8.50c	n.s.	14.60 ± 0.18c	n.s.	32.05 ± 3.17b	n.s.

TPC - Total phenolic content / *kopējo fenolu saturs*, mg GAE 100 g^{-1}
* Diferences in percentages for tested parameters between sauerkraut juice and concentrate/ *Pārbaudīto parametru procentuālās atšķirības starp skābētu kāpostu sulu un koncentrātu*
** n.s. – not significant / *nav būtisks*

Rotary vacuum evaporation significantly ($p<0.05$) increased antiradical activity by DPPH• and $ABTS^+$ methods in varieties 'Selma' and 'Kiloplons'. The results can be explained by the composition of the initial sample. Potential mechanisms implicated in the thermal breakdown of phenolic compounds consist of the liberation of phenolic compounds that were previously attached, the depolymerization of high molecular weight phenolics, the oxidation of phenolic compounds, and decomposition by oxidising enzymes, as is stated by Alizadeh et al. (2020). The content of lactic acid bacteria (LAB) in Sauerkraut juice and CSJ is variety dependent (Fig. 3.6.).

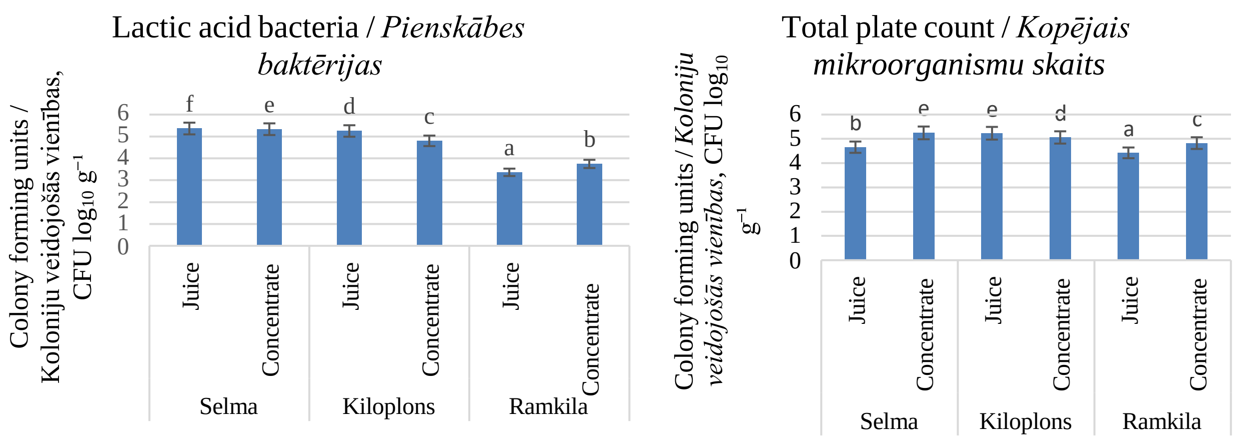

Fig. 3.6. **Lactic acid bacteria and total plate count in concentrated sauerkraut juice via rotary vacuum evaporation /**
3.6.att. Pienskābes baktēriju un kopējais mikroorganismu skaits rotācijas vakuuma ietvaicē koncentrētā skābētu kāpostu sulā

Variety 'Selma' samples showed sufficient numbers of bacteria (sauerkraut juice - $2{,}3\times10^5$ LAB count and concentrated sauerkraut juice - $2{,}15\times10^5$ CFU g^{-1} LAB count). Variety 'Ramkila' sauerkraut juice initially contained a lower amount of total plate count bacteria ($2{,}6\times10^4$ CFU g^{-1}) and thus also lactic acid bacteria ranging from $2{,}3\times10^3$ in sauerkraut juice to $5{,}5\times10^3$ CFU g^{-1} in concentrate.

Concentrated sauerkraut juice is a source of biologically active compounds, and can be used as a valuable raw material for innovative food products.

3.2.2. Concentrated sauerkraut juice via falling film and open kettle evaporation / *Krītošās plēves ietvaicē un atvērta tipa katlā koncentrēta skābētu kāpostu sula*

Falling film (FF) and open kettle (OD) evaporation was chosen because they were readily available and would provide an insight into industrially available evaporation equipment /technologies and their comparison.

The principles of falling film evaporator: the juice or liquid to be concentrated is distributed at the top of heating tubes letting flow down the inside of the tube walls as a thin film. The liquid is partially evaporated due to external heating of the heating tubes, enhanced by the parallel, downward flow of the vapour formed (Gong et al., 2020).

The analysed parameters of concentrated sauerkraut juice (CSJ) of industrial sample, before and after storage, and also open kettle evaporation results are displayed in Table 3.8.

FF CSJ is an industrial sample of harvest year 2019. It was evaporated in February 2020, and analysed in March 2020 and, after storage at 4 ± 2 °C, in September 2020. OD CSJ is an industrial sample of harvest year 2020. It was evaporated and analysed right after harvest and fermentation, in September 2020.

Table 3.8. / *3.8. tabula*

Physicochemical parameters of concentrated sauerkraut juice, DW / *Koncentrētas skābētu kāpostu sulas fizikāli ķīmiskie rādītāji, sausnā*

Parameters / *Parametri*	**Falling film evaporator** / *Krītošās plēves ietvaice*		**Open kettle** / *Atvērta tipa katls*
	Before storage / *Pirms uzglabāšanas*	**After storage** / *Pēc uzglabāšanas*	
pH / *pH*	3.92 ± 0.06a	3.86 ± 0.04a	3.90 ± 0.02a
Soluble solids / *Šķīstošā sausna*, Brix	34.3 ± 0.02a	34.74 ± 0.02a	17.9 ± 0.02b
Total phenols / *Kopējie fenoli*, mg GAE 100 g^{-1}	322.40 ± 12.69b	342.20 ± 8.89b	560.76 ± 11.51a
DPPH• / *DPPH•*, mg TE 100 g^{-1}	19.46 ± 0.36b	14.43 ± 0.22c	31.39 ± 1.21a
ABTS⁺ / *ABTS⁺*, mg TE 100 g^{-1}	19.01 ± 0.54a	17.31 ± 0.51b	16.82 ± 0.63b
Ascorbic acid / *Askorbīnskābe*, mg 100 g^{-1}	110.0 ± 4.34b	26.66 ± 2.47c	156.18 ± 5.62a
Lactic acid bacteria / *Pienskābes baktērijas*, CFU g^{-1}	4.6×10^4a	1.2×10^4b	4.4×10^3c
Total plate count / *Kopējais mikroorganismu skaits*, CFU g^{-1}	3.8×10^4b	1.6×10^5a	4.0×10^4b

Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem, norāda būtiskas atšķirības* ($p<0.05$)

While there was no significant difference ($p<0.05$) in pH between FF and OD concentrated sauerkraut juice, the TSS in the falling film concentrate was twice as high as in the open kettle sample. It was found that neither pH nor soluble solids were significantly affected by storage even after 6 months. pH of the CSJ was from 3.92 ± 0.06 at the beginning of this experiment to 3.86 ± 0.04 after 6 months. The initial pH of sauerkraut juice usually is 3.4 – 3.8.

FF evaporation is suitable for conserving heat-sensitive compounds, however, TPC, ascorbic acid content and antiradical activity by DPPH• is significantly higher in OD CSJ. These significant differences can be explained by different harvest years and all the factors influencing the crop, as well as the time of evaporation, mentioned earlier. Also, TPC acts differently in various juice concentrates. Storage caused significant reduction of antioxidant activity, but changes in TPC were insignificant (see table 3.8). Yang et al. (2020) have investigated the variation of TPC of dark fruit juices during storage and observed that TPC decreases at the first stages of storage, but over the time it increases again, assuming formation of different compounds. However, a few studies suggest that phenolic compounds remain stable and do not diminish in concentration throughout preservation (X. Yang et al., 2020).

Vitamin C, before the storage was 110 mg 100 g^{-1}, determined by HPLC (high-performance liquid chromatography). After the storage, ascorbic acid was determined titrimetrically and was 26.6 mg 100 g^{-1}, estimating only one of biologically active forms of vitamin C (Radenkovs et al., 2020). Dehydroascorbic acid is the second of two biologically active forms of vitamin C and, due to limitations in the analysis method, it was not determined to compare the content of vitamin C in FF CSJ after the storage.

Antiradical activity by DPPH• was 19.46 ± 0.36 mg TE 100 g^{-1} after the evaporation process, and it decreased to 14.43 ± 0.22 mg TE 100 g^{-1} after storage. There were fluctuations observed during storage in antiradical activity by DPPH• in oranges (Arena et al., 2001). The antiradical activity in black mulberry juice concentrate also decreased during storage and was influenced by many factors, like storage time, temperature and composition of the product (Dincer et al., 2016). The loss of ascorbic acid may have a contribution to decrease of antiradical activity (X. Yang et al., 2020). Antiradical activity by ABTS results were 19.01 ± 0.54 mg TE 100 g^{-1} at the beginning of the experiment and 17.31 ± 0.51 mg TE 100 g^{-1} after storage.

There is notable microbiological activity in concentrated sauerkraut juice during storage – decrease in lactic acid bacteria and significant increase in total plate count cfu. The viability and activity of microorganisms is influenced by many factors, such as pH, temperature, water activity etc. (Yang et al., 2020). Sauerkraut and its juice are considered a valuable source of lactic acid bacteria (LAB) (Yang et al., 2020) therefore survival of LAB during concentration process and storage impact was investigated. The LAB count after the evaporation process was 4.6×10^4 CFU g^{-1} but it decreased after 6 months of storage and was 1.2×10^4 CFU g^{-1}. Total plate count acted quite the opposite being 3.8×10^4 CFU g^{-1} after evaporation and 1.6×10^5 CFU g^{-1} after storage period.

For nutritional value FF CSJ was chosen, based on previous results, as it was suitable technology for concentration of juice with short evaporation time and highest TSS.

Concentrated sauerkraut juice contains carbohydrates as the main nutrient, followed by high ash content, including various minerals. Nutritional value of concentrated sauerkraut juice is summarised in Table 3.9.

As it is mentioned by other authors, the concentration of total sugars in sauerkraut samples varies from 0.3 to 1.7% wet weight, glucose being < 1 (Hughes & Lindsay, 1985). The sugar (glucose, fructose, sucrose) content varies in sauerkraut and its juice due to metabolic and microbiological activity (Xiong et al., 2016).

Due to high salt content, 6.33 g 100 g^{-1}, according to EU regulations (EC) No 1924/2006) CSJ can be used in food applications to substitute salt. Concentrated sauerkraut juice contains a variety of minerals, just like fresh cabbage, and the fermentation process may even increase the mineral content (Ifesan et al., 2014).

The ash content in concentrated sauerkraut juice is 9.42 g, thus it contains a variety of minerals like Mg, Cu, K, Ca, Fe as shown in Table 3.8. In comparison, fresh cabbage contains 200 – 300 mg 100 g^{-1} and fermented cabbage - 700 – 800 mg 100 g^{-1} minerals (Khanna, 2018). The role of minerals in human nutrition and metabolism is essential (Mensink et al., 2013), but the amount of potassium in this concentrate is noticeable, also iron, calcium, magnesium. It is the main cation in intracellular fluid and ensures cell function (Healthcare Research). Potassium is involved in regulating blood pressure, reduction of kidney stones and cardiovascular diseases[11] (Hmelak Gorenjak & Cencič, 2013).

Table 3.9. / *3.9. tabula*

Energy value and chemical composition of concentrated sauerkraut juice via falling film (FF) evaporation /

Krītošās plēves ietvaicē koncentrētas skābētu kāpostu sulas enrģētiskā vērtība un ķīmiskais sastāvs

Parameters / *Parametri*	**Unit /** *Mērvienība*	**Nutritional value /** *Uzturvērtība*, **100 g**	**RDI*[12]**
Energy value / *Enerģētiskā vērtība*	**kcal**	75	2000
Carbohydrates / *Ogļhidrāti*	**g**	13.0	260 g
- including sugars */ ieskaitot cukurus*	**g**	7.5	90 g
Glucose / G*likoze*	**g**	5.5	-
Fructose / *Fruktoze*	**g**	1.5	-
Maltose / *Maltoze*	**g**	0.2	-
Galactose / *Galaktoze*	**g**	0.3	-
- dietary fibre / *škiedrvielas*	**g**	1.1	-
Protein / *Olbaltumvielas*	**g**	5.3	50 g
Fat / *Tauki*	**g**	<0.1	70 g
Ash / *Pelnvielas*	**g**	9.42	-
Salt / *Sāls*	**g**	6.33	6 g
Minerals / *Minerālvielas*			
Magnesium / *Magnijs*	**mg**	67.80	375 mg
Copper / *Varš*	**µg**	113.62	1 mg
Potassium / *Kālijs*	**mg**	1358.32	2000 mg
Calcium / *Kalcijs*	**mg**	238.34	800mg
Iron / *Dzelzs*	**µg**	1137.34	14 mg
Nitrates / *Nitrāti*			
Nitrates as $NaNO_3$	**mg**	151.01	-
Nitrates as NO_3^-	**mg**	110.22	-

*RDI – Recommended Daily Intake / *Ieteicamā dienas deva*

Brassicaceae (rocket, mustard as well as cabbage) vegetables are considered as nitrate accumulating sources like many green leafy vegetables, and there is a large variation in concentration which is influenced by many factors. The nitrate concentration in leafy vegetables is regulated by the European Commission (Commission, 2010) and the nitrate content is considered as very low if it is below 200 mg 100 g^{-1} fresh weight (Hmelak Gorenjak & Cencič, 2013). The nitrate content in concentrated sauerkraut juice is considered as low with no harmful impact on health, according to WHO (World Health Organisation). Since the concentrated sauerkraut juice is a condiment, not a regular provision, it is not regarded as a source of minerals for daily intake.

[11]Center for Disease Prevention and Control / *Slimību profilakses un kontroles centrs*

[12] Regulation of Cabinet of Minister Nr. 461, Requirements for food quality schemes, their implementation, operation, monitoring and control procedures

The open kettle technology was not further analysed, since it was time and energy consuming, the maximum of total soluble solids reached 18 °Brix, which had a potential of higher microbiological activity during storage and shorter storage time in general.

Summary of Chapter 3.2. / *3.2. nodaļas kopsavilkums*

The study investigated three evaporation techniques – rotary vacuum, falling film and open kettle evaporation, to obtain concentrated sauerkraut juice (CSJ). Rotary vacuum evaporation was carried out from three different sauerkraut juice varieties. The comparison of acquired concentrate is reflected in Figure 3.7. Samples FF BS/FF AS (Falling film evaporation before storage and after storage for 6 months) and OD are an industrial sample, and possess a higher amount of TPC as well as they were concentrated from different crops in different harvest years.

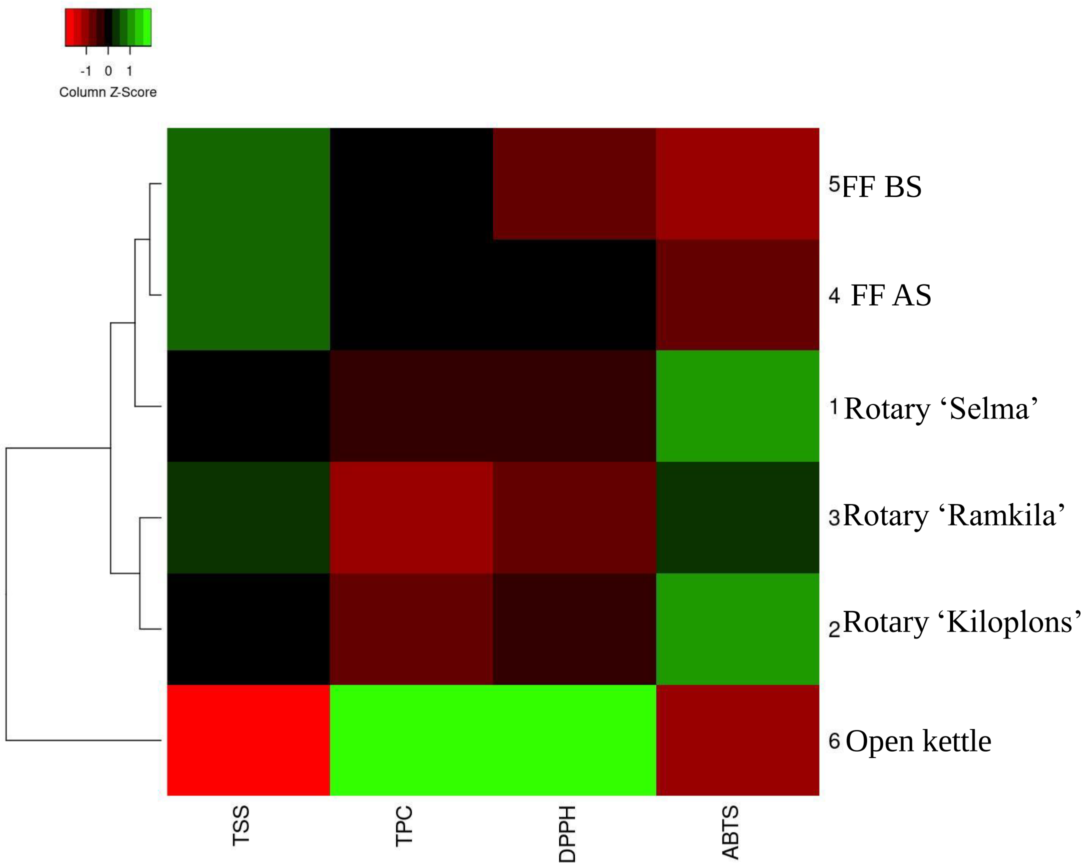

Fig.3.7. **TPC and antiradical activity in concentrated sauerkraut juice, DW /**
3.7. att. Kopējo fenolu saturs un antiradikālā aktivitāte koncentrētā skābētu kāpostu sulā
TSS – total soluble solids / *šķīstošā sausna*
TPC - Total phenolic content / *kopējo fenolu saturs*, mg GAE 100 g $^{-1}$
DPPH•; ABTS^{+} - Antiradical activity / *antiradikālā aktivitāte*, mg TE 100 g $^{-1}$
*DW – dry weight / *sausna*

Rotary vacuum evaporation significantly increased antiradical activity by ABTS^{+} (green colour in Fig.3.7.) in varieties 'Selma' and 'Kiloplons'. LAB counts were highest in the variety 'Selma' samples. Falling film (FF) evaporation was found to produce a concentrate with twice the TSS (total soluble solids) (dark green colour in Fig.3.7.) compared to open kettle evaporation (bright red in Fig.3.7.), but lower levels of total phenol compounds (TPC) and antiradical activity by DPPH•. Storage caused a decrease in antiradical activity, ascorbic acid, and lactic acid bacteria (LAB) count in FF CSJ, but TPC remained stable. The study suggests that the differences in results could be attributed to different harvest years and processing times.

CSJ was found to be a source of ascorbic acid and phenol compounds, also minerals, potassium being the most abundant, iron, calcium, magnesium. It can be used as a valuable raw material for innovative food products or as a substitute for salt. Shelf life of concentrated juices vary depending on raw materials and are from one year to three years (Salehi, 2020).

Pētījumā izpētīja trīs ietvaices tehnikas – rotējošo vakuuma, krītošās plēves un atklāta tipa katla ietvaicēšanu, iegūstot koncentrētu skābētu kāpostu sulu (CSJ). Rotējošā vakuuma ietvaicē tika pētītas atšķirības sulai, iegūtai no trīs kāpostu šķirnēm. Iegūtā koncentrāta salīdzinājums ir atspoguļots 3.6. attēlā. Paraugi FF BS/FF AS (krīstošās plēves ietvaice pirms uzglabāšanas un pēc 6 mēnešu uzglabāšanas) un OD ir rūpnieciskie paraugi, un uzrāda lielāku kopējo fenolu saturu. Tie ir skābēti un sula koncentrēta dažādos gados un no dažādām ražām.

Rotācijas vakuumietvaice būtiski palielināja antiradikālo aktivitāti 'Selma' un 'Kiloplons' šķirnes sulām. Pienskābes baktēriju (LAB) skaits visaugstākais bija šķirnes 'Selma' sulas paraugos. Tika konstatēts, ka krītošās plēves (FF) iztvaikošana rada koncentrātu ar divas reizes lielāku kopējo šķīstošo sausnu (TSS), salīdzinot ar rezultātiem atvērtā tipa katla ietvaicē, bet kopējo fenolu savienojumi (TPC) un DPPH antiradikālā aktivitāte ir būtiski zemāka. Uzglabāšanas rezultātā samazinājās antiradikālā aktivitāte, askorbīnskābe un LAB skaits FF CSJ, bet TPC palika stabils. Pētījums liecina, ka rezultātu atšķirības varētu attiecināt uz dažādiem ražas gadiem un pārstrādes laikiem.

Tika konstatēts, ka CSJ ir askorbīnskābes, fenolu savienojumu un minerālvielu avots. CSJ ir ievērojama kālija koncentrācija, bet satur arī dzelzi, kalciju un magniju. To var izmantot kā vērtīgu izejvielu, izstrādājot novatoriskus pārtikas produktus, vai izmantot kā sāls aizstājēju. Koncentrētu sulu uzglabāšanas laiks ir atkarīgs no to izejvielām un parasti ir no viena līdz trim gadiem (Salehi, 2020).

3.3. Development of dehydrated sauerkraut juice / *Dehidrētas skābētu kāpostu sulas izstrāde*

3.3.1. Results on horizontally spray-dried sauerkraut juice / *Horizontālā izsmidzināšanas kaltē iegūto rezultātu pārskats*

Overall characteristics of horizontally spray-dried sauerkraut juice (DSJ) is compiled in Table 3.10. Horizontal spray-drying was selected based on research performed by Lidums I., (Production and quality of dehydrated rye bread kvass / *Dehidrēta rudzu maizes kvasa ieguve un kvalitāte, 2018.)* as a prospective technology for heat sensitive products.

The amount of NaCl in the horizontally spray-dried samples (Fig 3.10) with different maltodextrin (MD) concentrations ranged from 8.70 g 100 g^{-1} in the samples with 10% MD to 14.31 g 100 g^{-1} in the samples with no MD additive. Following the EU regulations (EU science HUB, Health promotion and disease prevention), the observed value of NaCl in sauerkraut juice obtained by horizontal spray drying approach is considered high. Therefore, the developed product could represent a potential application in the food industry as a salt substitute. According to Latvian legislation[13] the final content of additional salt in meat products is 1.25 g per 100 g, and therefore the powder without coating agent could be added up to 9%, if acceptable for other quality parameters.

Moisture content is influenced by MD presence, samples without carrier agent contain more moisture, as is observed in asparagus and sweet potato powders (Fabra et al., 2011; Siccama et al., 2021). Solubility of DSJ in water is considered as good (high solubility > 97%) (Largo Ávila et al., 2015) ranging from 81.74 to 82.80%. In comparison, the solubility of litchi

[13] Regulation of Cabinet of Minister Nr. 461, Requirements for food quality schemes, their implementation, operation, monitoring and control procedures

juice powder was found to be 68.11 (Kalita et al., 2018). Based on these parameters, MD had an acceptable effect on DSJ and thus was considered to be suitable for further use in food production.

There was a significant effect (see Table 3.10) of MD concentration on titratable acidity, showing the highest value for the sample 4MD0.

Table 3.10. / *3.10. tabula*

Physicochemical parameters of horizontally spray-dried sauerkraut juice, DW /
Horizontālā izsmidzināšanas kaltē dehidrētas skābētu kāpostu sulas fizikāli ķīmiskie rādītāji, sausnā

Dehydrated sauerkraut juice *Dehidrēta skābētu kāpostu sula*	**NaCl, %** *Sāls, %*	**Moisture content, %** *Mitrums, %*	**Solubility in water, %** *Šķīdība ūdenī, %*	**Titratable acidity/** *Titrējamais skābums,* **g 100 g⁻¹**	**MD / $CaCO_3$ concentration /** *Koncentrācija*
1MD10	8.70 ± 0.34c	5.08 ± 0.28b	81.74 ± 0.66a	0.35 ± 0.11b	10 / 5
2MD10	8.93 ± 0.07c	5.30 ± 0.23b	82.76 ± 0.82a	0.36 ± 0.07b	10 / 3
3MD5	12.23 ± 0.18b	7.04 ± 0.02a	82.80 ± 0.21a	0.38 ± 0.09b	5 / 5
4MD0	14.31 ± 0.07a	7.03 ± 0.14a	82.57 ± 054a	0.44 ± 0.09a	0 / 5

Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem, norāda būtiskas atšķirības* ($p<0.05$)

There were two extraction methods used in our study to determine total phenol content and antiradical activity in dehydrated sauerkraut juice. Extraction in water was chosen since the future use of dehydrated juice is planned to be in food production (bread, meat), hence dilution in water. Due to previous findings by Gouw et.al. (Gouw et al., 2017) an acidified ethanol extraction in an ultrasonic water bath was also used to compare extraction efficiency and observe changes of phenolic compounds and antiradical activity. The comparison of TPC results is shown in Figure 3.8. and antiradical activity in Table 3.11.

Statistically significant differences in total phenolic content (TPC) were observed when comparing different extraction methods.

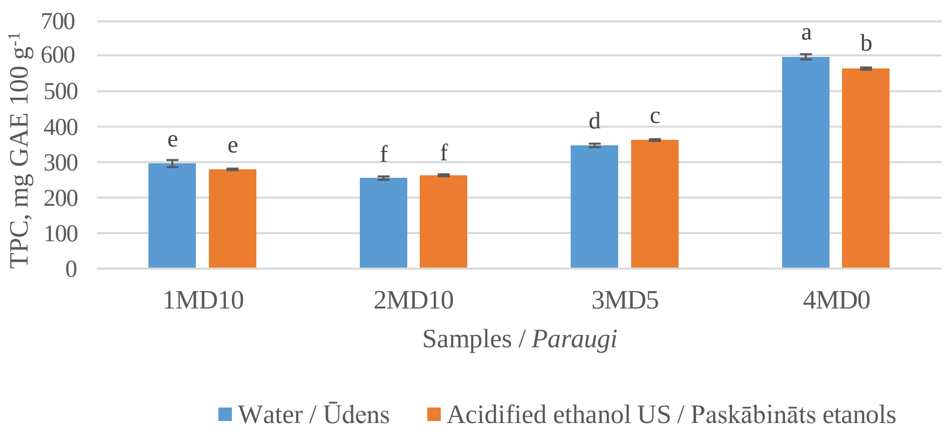

Fig. 3.8. **TPC of horizontally spray-dried sauerkraut juice, DW /**
3.8. att. Horizontālā izsmidzināšanas kaltē dehidrētas skābētu kāpostu sulas kopējo fenolu saturs, sausnā
Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem, norāda būtiskas atšķirības* ($p<0.05$)
1MD10 – 10% maltodextrin, $CaCO_3$ 5g^{-1} L; 2MD10 – 10% maltodextrin, $CaCO_3$ 3 g^{-1} L
3MD10 – 5% maltodextrin, $CaCO_3$ 5 g^{-1} L; 4MD10 – 0% maltodextrin, $CaCO_3$ 5 g^{-1} L

The sample with 0% and 5% of MD addition showed the greatest difference. The highest TPC was found in the 4MD0 water extraction, while the lowest was observed in the sample 2MD10, which contained 10% MD and $CaCO_3$ at a concentration of 3 g^{-1} L for water extraction. As found by Shishir and Chen (2017) carrier agents may not always preserve TPC and free radical scavenging activity, as observed by the lower TPC in samples with higher MD amounts – 1MD10 AND 2MD10 (Table 3.11.).

Table 3.11. / *3.11. tabula*

Antiradical activity of horizontally dehydrated sauerkraut juice /
Horizontālā izsmidzināšanas kaltē dehidrētas skābētu kāpostu sulas kopējo fenolu saturs un antiradikālā aktivitāte, mg TE 100 g^{-1}

Sample / *Paraugs*	**DPPH•**		**ABTS**	
	Water / *Ūdens*	**Acidified ethanol US /** *Paskābināts etanols US*	**Water /** *Ūdens*	**Acidified ethanol US /** *Paskābināts etanols US*
1MD10	12.72 ± 0.31d	34.55 ± 0.78b	13.30 ± 0.52d	17.18 ± 0.43c
2MD10	12.17 ± 0.38d	34.20 ± 0.48b	12.65 ± 0.76d	17.77 ± 0.49c
3MD5	14.14 ± 0.18c	35.55 ± 0.33b	13.16 ± 0.64d	18.97 ± 0.58b
4MD0	14.64 ± 0.06c	38.50 ± 0.50a	17.85 ± 0.43c	26.43 ± 0.65a

Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem, norāda būtiskas atšķirības* ($p<0.05$)
DPPH•; ABTS - Antiradical activity / *antiradikālā aktivitāte*
1MD10 – 10% maltodextrin, $CaCO_3$ 5g^{-1} L; 2MD10 – 10% maltodextrin, $CaCO_3$ 3 g^{-1} L
3MD10 – 5% maltodextrin, $CaCO_3$ 5 g^{-1} L; 4MD10 – 0% maltodextrin, $CaCO_3$ 5 g^{-1} L

The results show moderate (r = 0.67 for DPPH•) to strong correlation (r = 0.93 $ABTS^+$) between the applied methods, and total phenol concentration was also significantly correlated with antiradical activity (r = 0.83–0.89), which indicates that TPC reflects antiradical activity

Antiradical activity extracted by acidified ethanol is significantly higher ($p<0,05$) than water extraction. Our study showed a significant effect ($p<0.05$) of maltodextrin on TPC using both extraction methods. In the samples with no MD added, the phenol content was 596 ± 7.43 mg100 g^{-1} DW in water extracts and 563 ± 3.12 mg GAE 100 g^{-1} DW in acidified ethanol extracts. In sample 2MD10 the total phenol content was 254.74 ± 4.78 mg GAE 100 g^{-1} in water extracts and 262.77 ± 2.62 mg GAE 100 g^{-1} DW in acidified ethanol extracts. The concentration of carrier agents is compound sensitive – increased MD content may decrease in active compound content (Krishnaiah et al., 2014).

Organic acid content in dehydrated sauerkraut juice is affected by maltodextrin concentration. In total 6 organic acids were identified in dehydrant. Four major ones being oxalic, lactic, acetic and quinic acids, shown in Fig. 3.9. Malic and ascorbic acids were present in negligible amounts.

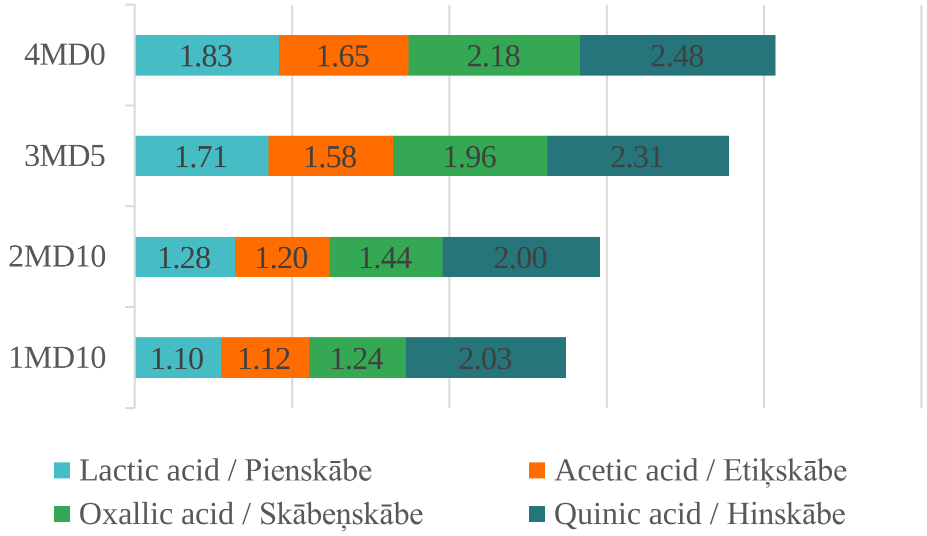

Fig. 3.9**. Organic acid content in horizontally dehydrated sauerkraut juice, g 100 g^{-1}, FW/**
3.9. att. Horizontālā izsmidzināšanas kaltē dehidrētas skābētu kāpostu sulas organisko skābju profils, g 100 g^{-1} produkta
1MD10 – 10% maltodextrin, $CaCO_3$ 5g^{-1} L; 2MD10 – 10% maltodextrin, $CaCO_3$ 3 g^{-1} L
3MD10 – 5% maltodextrin, $CaCO_3$ 5 g^{-1} L; 4MD10 – 0% maltodextrin, $CaCO_3$ 5 g^{-1} L

Like all other chemical compositions, also organic acid profile can be influenced by many factors like state of raw material, fermentation process, microorganism absence and many others (Shukla et al., 2010; Jansone et al., 2022). While oxalic and ascorbic acids are naturally present in fresh cabbage, lactic, acetic and, some others, are formed during fermentation process (Drašković Berger et al., 2020a; Jansone et al., 2022). Organic acids formed via metabolism of large molecular mass compounds influence the taste and aroma of fermented products (Shukla et al., 2010). The intake of oxalic acid in European diets was estimated to be in the range of 5 mg to 500 mg per day, seasonally exceeding 1000 mg per day[14]. Oxalic acid occurs in green leafy vegetables, consumed during the growing season. In our study, concentration of oxalic acid was 1.24 g (MD10) to 2.18 g (MD0) 100 g^{-1} and theoretical intake with DSJ is insignificant.

In order to determine the benefits of spray-drying sauerkraut juice, we tested the viability of microorganisms in DSJ, in relation to addition of maltodextrin. According to FAO/ WHO (2006) a functional food with a probiotic potential should reach at least 10^7 CFU g^{-1}. In our study, dehydrated sauerkraut juice did not meet this standard, Figure 3.10. There was a major impact of maltodextrin in our samples on bacterial counts, with a range from 8.9×10^3 CFU in MD1 to 4.2×10^4 CFU in MD0 samples. Similar results were reported for kefir powder (Teijeiro et al., 2018).

[14] The European Agency for the Evaluation of Medicinal Products Veterinary Medicines and Inspections committee for veterinary medicinal products oxalic acid summary report, 2003

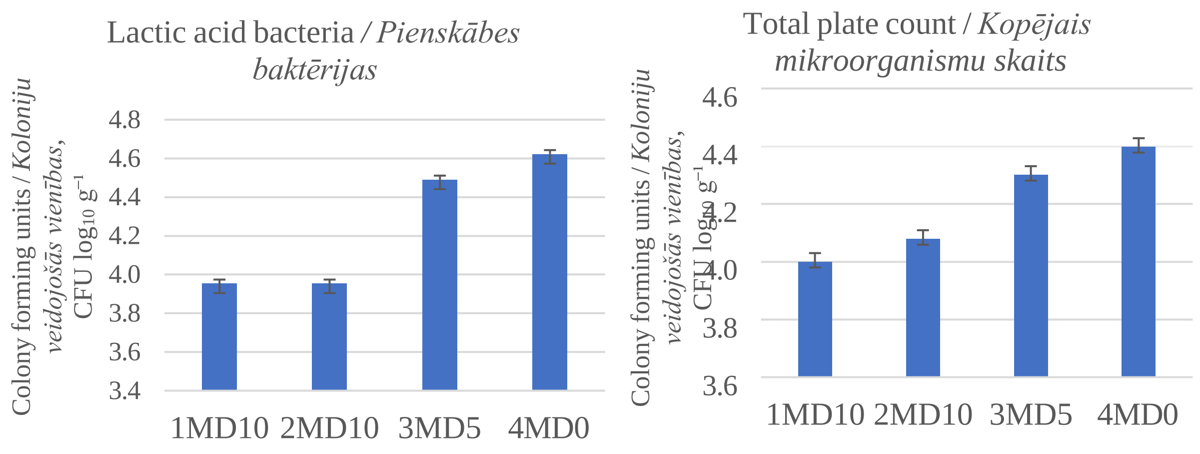

Fig. 3.10**. Lactic acid bacteria and total plate count cfu^{-1} in dehydrated sauerkraut juice via horizontal spray-dry**

3.10. att. Pienskābes baktēriju un kopējais mikroorganismu skaits kvv^{-1} horizontālā izsmidzināšanas kaltē dehidrētā skābētu kāpostu sulā

A combination of effects influences the viability of microorganisms — heat, mechanical stress, pre- and post-processing, the use of coating agents, storage (Lira de Medeiros et al., 2014; Dianawati et al., 2016; Kalita et al., 2018; Teijeiro et al., 2018) observed that cell viability decreased during storage using MD as a coating agent — the survival of *L. plantarum* decreased significantly in litchi juice powder, spray-dried with MD, compared to MD – pectin and MD – fructo-oligosacharide as coating agents. However, Medeiros et al. (2014) and Teijeiro et.al. (2018) observed that survival of lactic acid bacteria (LAB) was better when spray-dried with a coating agent and maltodextrin had the best effect. This is in contrast with our study, where samples with 5% and 0% of MD addition show better survival of LAB. There was a strong (0.98) correlation between LAB and total plate count. Kalita et. al. (2018) also observed that pH of around 4 had less severe effect on probiotics than pH 2. Teijero (2018) stated that for kefir powder the combination of whey permeate and maltodextrin and neutral pH (7) resulted in better lactic acid bacteria survival, and suggested that the acidic conditions during dehydration of kefir-derived LAB was the main factor affecting their survival.

3.3.2. Results on vertically spray-dried sauerkraut juice/ *Vertikālā izsmidzināšanas kaltē iegūto rezultātu pārskats*

There are some limitations on horizontal spray-drying due to large quantities and tight possibilities of changing drying parameters. In order to find the optimal drying parameters for dehydrating juice on vertical spray-dryer, an industrial sample of pasteurised juice (PJ) produced by "Dimdiņi" Ltd was spray-dried variong in MD concentrations and temperature. The initial temperature regimes and MD concentrations were chosen according to horizontally spray-dried samples. These tests were abortive. Successful parameters used in horizontal spray-dryer did not work on vertical spray-dryer. The size of the drying equipment is one of the main factors to obtain a successful result. Different drying parameters and carrier agents were tested and are describe in Table 3.12.

Table 3.12. / *3.12. tabula*

Drying parameters and carrier agents tested for vertically spray-drying of sauerkraut juice/ *Vertikālā izsmidzināšanas kaltē testētie kaltes parametri un nesējvielas, kaltējot skābētu kāpostu sulu*

		
Carrier agent/ *Nesējviela*	**Drying parameters/** *kaltēšanas parametri*	**Result/** *Iznākums*
10% wet wight (ww) Maltodextrin (MD), dextrose equivalent (DE) 10-14 / *10% maltodekstrīns no kopējās masas, dekstrozes ekvivalents 10-14*	I.t 135 °C, aspirator 75%, pump 15%, flow 55 mm (tested various parameters) / *aspirators 75%, sūknis 15%, plūsma 55 mm (dažādas parametru variācijas)*	Sticky powder / *lipīgs pulveris*
+ $CaCO_3$	I.t. 135 °C, aspirator 75%, pump 15%, flow 55	Not possible to dry / *nav iespējams izkaltēt*
+$CaCl_2$ + NaOH	I.t. 135 °C, aspirator 75%, pump 15%, flow 55	Extremely salty / *ļoti sāļš*
+$CaCl_2$ + NaOH + 5%MD	I.t. 135 °C, aspirator 75%, pump 15%, flow 55	Crystalized agglomerates / *kristalizēti aglomerāti*
5% inulin / *inulīns* 10% inulin / *inulīns*	I.t. 140 °C, aspirator 80%, pump 15%, flow 25	Sticks to the dryer walls / *līp pie kaltes sienām*
5% inulin / *inulīns* + 5% dextrose / *dekstroze*	I.t. 160 °C, aspirator 90%, pump 55%, flow 45	Did not obtain – sticky mass on the wall / *neieguva, lipīga masa pie kaltes sienām*
20% dextrose / *dekstroze*	I.t. 140 °C, aspirator 80%, pump 30%, flow 40	Did not obtain – sticky mass on the wall / *neieguva, lipīga masa pie kaltes sienām*
5% MD + 5% polydextrose / *polidekstroze* (PD) (various concentrations / *dažādas* *koncentrācijas* 5% MD +2.5% PD; 2.5% MD +5% PD)	I.t. 180 °C, aspirator 50%, pump 20%, flow 45	Carrier agent is spray dried, juice sticks to walls, encapsulation segregates / *iekapsulēšana neveiksmīga, nesējviela izkaltējas, sula pielīp pie kaltes sienām*
5% Polidextrose / *polidekstroze* +5% inulin / *inulīns*	I.t. 180 °C, aspirator 90%, pump 35%, flow 45	Sticks to the dryer walls / *līp pie kaltes sienām*

Continuation of the table 3.12. /
3.12. tabulas turpinājums

Carrier agent/ *Nesējviela*	**Drying parameters/** *kaltēšanas parametri*	**Result/** *Iznākums*
10% Polidextrose / *polidekstroze*	I.t. 180 °C, aspirator 90%, pump 35%, flow 40	Hard, granular, crystallised outcome / *cietu granulu pulveris*
Starch solution (1:20) various proportions / *cietes šķīdums dažādās koncentrācijās*	Various parameters	Jam-like consistency / *ievārījumam līdzīga konsistence*
1-part juice / *sula* + 1.5 parts starch solution (1:20) / *cietes šķīdums*	I.t. 150 °C, aspirator 70%, pump 30%, flow 35	Granular-like powder / *graudains pulveris*
1 part juice / *sula* + 1. part starch solution (1:20) / *cietes šķīdums* + 0.6 part MD	I.t. 150 °C, aspirator 70%, pump 30%, flow 35	Powder-like consistency / *pulvera konsistence*
1 part juice / *sula* **+ 1.5 parts starch solution (1:20)/** *cietes šķīdums*	**I.t. 140 °C, aspirator 65%, pump 25%, flow 35**	**A dehydrated sauerkraut juice /** *dehidrēta skābētu kāpostu sula*

*I.t – inlet air temperature / *ieejošā gaisa temperatūra*

Due to previous studies, (Kalita et al., 2018; Teijeiro et al., 2018) $CaCo_3$, NaOH and $CaCl_2$ were added to the matrix to neutralise pH, that would avoid the stickiness and jam-like consistency. The obtained results, neutralising sauerkraut juice were not satisfactory and further experiments were not carried out.

Various high molecular carbohydrates were chosen due to their high glass transition temperature (T_g) to avoid sticky mass on the dryer's walls (Krishnaiah et al., 2014).

Starch solution and a mixture of starch solution and maltodextrin were used to obtain dehydrated sauerkraut juice. The description of samples and proportions is given in Table 3.13. Inlet/outlet temperatures 150/70-74 °C, feed flow rate 35 mL min^{-1}.

Table 3.13. / *3.13. tabula*

Description of sample preparation for vertical spray drying /
Paraugu sagatavošanas parametri vertikālai izsmidzināšanas kaltei

Sample / *Paraugs*		**Proportion: solution / juice, g** *Proporcija: šķīdums / sula, g*	**Maltodextrin** / *Maltodekstrīns* **(DE 10-14),** g	**TSS, ° Brix/** *Šķīstošā sausna*
Juice with starch solution / *Sula ar cietes šķīdumu*	**PJ SS**	75/50	–	6.70
Juice with starch solution; maltodekstrin / *Sula ar cietes šķīdumu un maltodekstrīnu*	**PJMD**	50/50	3.00	10.00

As previously explained, experimental work was conducted to test various ratios of starch solution to sauerkraut juice for the dehydration process. The results showed that a ratio of 75:50 (starch solution to sauerkraut juice) was optimal, resulting in dehydrated sauerkraut juice. When all the parameters were clear and dehydrated sauerkraut juice was obtained, sauerkraut juice of two varieties 'Selma' and 'Kiloplons' were then spray-dried.

Overall characteristics of dehydrated sauerkraut juice (DSJ) of two varieties and industrial sample (PJ), spray-dried with different carrier agents, is presented in Table 3.14.

Table 3.14. / *3.14. tabula*

Physicochemical parameters of vertically dehydrated sauerkraut juice /
Vertikālā izsmidzināšanas kaltē dehidrētas skābētu kāpostu sulas fizikāli ķīmiskie rādītāji

Dehydrated sauerkraut juice / *Dehidrēta skābētu kāpostu sula*	**NaCl, %** *Sāls, %*	**Moisture content, %** *Mitrums, %*	**Solubility in water, %** *Šķīdība ūdenī, %*
PJ SS	8.83 ± 0.14c	6.99 ± 0.54c	88.62 ± 0.26a
PJ MD	8.45 ± 0.17c	7.29 ± 0.15c	88.48 ± 0.42a
Selma SS	11.70 ± 0.16a	11.38 ± 0.32a	87.80 ± 0.31a
Kiloplons SS	12.05 ± 0.16a	11.82 ± 1.03a	88.30 ± 0.71a
Selma MD	9.93 ± 0.03b	9.65 ± 0.41b	87.22 ± 0.88a
Kiloplons MD	9.83 ± 0.08b	9.44 ± 0.17b	87.71 ± 0.02a

Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem, norāda būtiskas atšķirības* ($p<0.05$).
SS – starch solution / *cietes šķīdums*, MD – maltodextrin / *maltodekstrīns*, PJ – industrial sample */ rūpnieciskais paraugs*

There are significant differences ($p<0.05$) among the physicochemical parameters of the samples. Salt content was found to be lower in the samples dried with MD additive and can be attributed to higher TSS. These samples posses a smaller moisture content as well. Also, there are substantial differences - samples with starch solution are making caramelised agglomerates, Fig. 3.11. All of the samples have good water solubility.

There are insignificant differences in physicochemical parameters, but variation in composition of carrier agents is acceptable and can be suitable in applications in various food technologies.

A B

Fig. 3.11. **Dehydrated sauerkraut juice on a vertical spray-dryer; (A) samples dried with starch solution and (B) starch solution and maltodextrin additive /**
3.11. att. Vertikālā izsmidzināšanas kaltē iegūta skābētu kāpostu sula. A – ar cietes šķīdumu; B – ar cietes šķīdumu un maltodekstrīnu

To determine TPC and antiradical activity water extraction was used for these samples. There are differences in results when encapsulating sauerkraut juice with starch solution and mixture of maltodextrin and starch solution. TPC and antiradical activity by DPPH• is higher in the samples spray-dried with starch solution thus TPC is better preserved. The stability of total phenolic concentration and antiradical activity is affected by the choice of the coating agent and spray drying technique. For the retention of heat sensitive compounds, the inlet and outlet temperature are of great importance (Fang & Bhandari, 2011). Previous studies (Kha et al.,2010; Fang & Bhandari, 2011; Krishnaiah et al., 2014) have suggested that the optimum parameters for spray-drying process to preserve TPC and antiradical activity is outlet temperature 120 °C and 10% (wet weight) maltodextrin.

Comparison of TPC and antiradical activity of vertically dehydrated juice is given in Table 3.15.

Table 3.15. / *3.15. tabula*

TPC and antiradical activity of vertically dehydrated sauerkraut juice /
Vertikālā izsmidzināšanas kaltē dehidrētas skābētu kāpostu sulas kopējo fenolu saturs un antiradikālā aktivitāte

Dehydrated sauerkraut juice / *Dehidrēta skābētu kāpostu sula*	**Parameters /** *Rādītāji*, **mg 100 g⁻¹ DW**		
	Total phenol content/ *Kopējais fenolu saturs*	**DPPH•***	**ABTS**
PJ SS	284.48 ± 6.01b	22.12 ± 1.41a	19.37 ± 1.61d
PJ MD	259.89 ± 3.12c	19.62 ± 0.22c	18.31 ± 1.21d
Selma SS	363.46 ± 5.99a	22.68 ± 0.25a	24.17 ± 0.79c
Kiloplons SS	359.54 ± 7.77a	22.62 ± 0.15a	39.02 ± 2.03b
Selma MD	295.43 ± 6.42b	21.09 ± 0.17b	68.28 ± 1.46a
Kiloplons MD	298.21 ± 5.76b	21.01 ± 0.27b	63.44 ± 2.13a

Total phenolic content / *kopējo fenolu saturs*, mg GAE 100 g $^{-1}$
*DPPH•; ABTS^{+} - *Antiradical activity / antiradikālā aktivitāte,* mg TE 100 g $^{-1}$
Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem, norāda būtiskas atšķirības* ($p<0.05$).
SS – starch solution / *cietes šķīdums*, MD – maltodextrin / *maltodekstrīns*, PJ – industrial sample / *rūpnieciskais paraugs*

Increased MD concentration results in decrease of total antioxidant activity because MD can bind to the antioxidants in the juice during the drying process, causing them to become less available and therefore less effective (Krishnaiah et al., 2014). Feed flow affects antioxidant compounds and moderate flow (7.5 ml min^{-1}) can promote antioxidant activity (Romano et al., 2020).

Maltodextrin influence on TPC is seen in all of the dried samples. Drying with a starch solution, TPC is better preserved. But the moisture content is higher, thus microbiological and enzymatic activity may occur and change the stability and content of active compounds. Microbiological activity in dehydrated sauerkraut juice is shown in Figure 3.13.

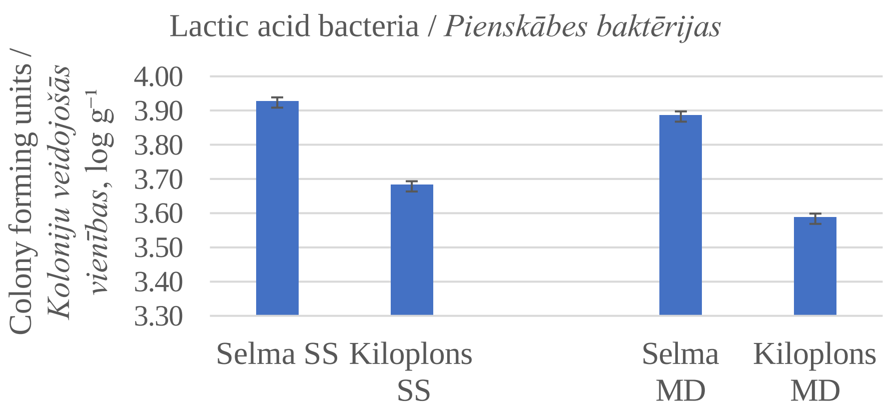

Fig. 3.12. **Lactic acid bacteria in vertically spray dried sauerkraut juice with different carrier agents /**
3.12. att. Pienskābes baktērijas[1] vertikālā kaltē izsmidzinātā skābētu kāpostu sulā

The ‘Selma’ variety showed the highest number of lactic acid bacteria (LAB) in sauerkraut juice, and even after spray drying, it maintained the highest LAB count. This was observed in samples that were sprayed with starch solution alone as well as with a combination of starch solution and maltodextrin.

Nutritional value of vertically dehydrated sauerkraut juice

The nutritional characteristics of vertically spray-dried sauerkraut juice (DSJ) is given in Table 3.16. The breakdown of starch during the spray-drying process and the natural presence of sugars in sauerkraut juice are possible explanation to energy value and carbohydrates content in DSJ (Araujo-Silva et al., 2018), including sugars glucose, fructose, and maltose

The ash content in DSJ is 15.28 g 100 g^{-1}, and thus, there is a wide array of minerals, as shown in Table 3.16.

Table 3.16. / *3.16. tabula*

Nutritional value of vertically spray-dried sauerkraut juice, harvest year 2021 / *Vertikālā izsmidzināšanas kaltē dehidrētas skābētu kāpostu sulas uzturvērtība, 2021. ražas gads*

Parameters / *Rādītāji*	**Unit** / *Mērvienība*	**DSJ** / *Dehidrēta skābētu kāpostu sula*, 100 g
Energy value / *Enerģētiskā vērtība*	kcal	294.7
Fat / *Tauki*	g	<0.1
Carbohydrates / *Ogļhidrāti*	g	61.8
- including sugars / *tai skaitā cukuri*		
Glucose / *Glikoze*	g	8.7
Fructose / *Fruktoze*	g	4.3
Maltose / *Maltoze*	g	9.8
Total sugars / *Kopējie cukuri*	g	27.1
- dietary fiber / *šķiedrvielas*	g	5.4
Protein / *Olbaltumvielas*	g	6.5
Ash / *Pelnvielas*	g	15.28

The NaCl content in DSJ contributes to the amount of ash, to some content. DSJ may not be considered an everyday condiment, yet the amount of minerals present in the DSJ is significant. Daily reference intakes (DRI) for vitamins and minerals, according to EU regulation 1169/2011[15] , are presented in Table 3.17.

Table 3.17. / *3.17. tabula*

Mineral content and vitamin C in dehydrated sauerkraut juice and daily reference intake, harvest year 2021 / *Minerālvielu un C vitamīna saturs dehidrētā skābētu kāpostu sulā, 2021. ražas gads, un ieteicamā dienas deva*

Minerals / *Minerālvielas*	**mg 100 g^{-1}**	**DRI***	**15 % of the nutrient reference values** / *15% no ieteicamās dienas devas*
Magnesium / *Magnijs*	88,7	375	56.2
Manganese / *Mangāns*	1.1	2	0.3
Copper / *Varš*	0.1	1	0.15
Potassium / *Kālijs*	1457	2000	300
Calcium / *Kalcijs*	296.8	800	120
Iron / *Dzelzs*	1.5	14	2.1
Vitamin C / *C vitamīns*	98	80	12

*- Daily reference intake / *Ieteicamā dienas deva*

[15] Regulation (EU) of the European Parliament and Council No. 1169/2011 on providing information on food products to consumers

A product can be considered significantly nutritious if it contains at least 15% of nutrient reference values per 100 g. This means that a serving of that product would contribute significantly to a person's daily nutrient needs. Potassium being the most abundant element in DSJ, contributed most to daily intake, along with manganese and calcium. Despite the potentially harsh nature of the spray-drying process, a considerable amount of vitamin C remained in the DSJ sample, with the specific sample containing 98 mg 100 g^{-1}.

Volatile compounds in sauerkraut juice and dehydrated sauerkraut juice

Sauerkraut juice and its products have a very distinct flavour and aroma that is composed of various volatile compounds, like aldehydes, alcohols, sulphur compounds, esters, ketones, terpenes, furans etc. (Rajkumar et al., 2017) and can be metabolised to bioactive compounds, delivering health promoting benefits (Goff & Klee, 2006). The profile of volatiles was determined for sauerkraut juice and dehydrated sauerkraut juice and results exceeding 5% of volatile compound content, are presented in Figure 3.13.

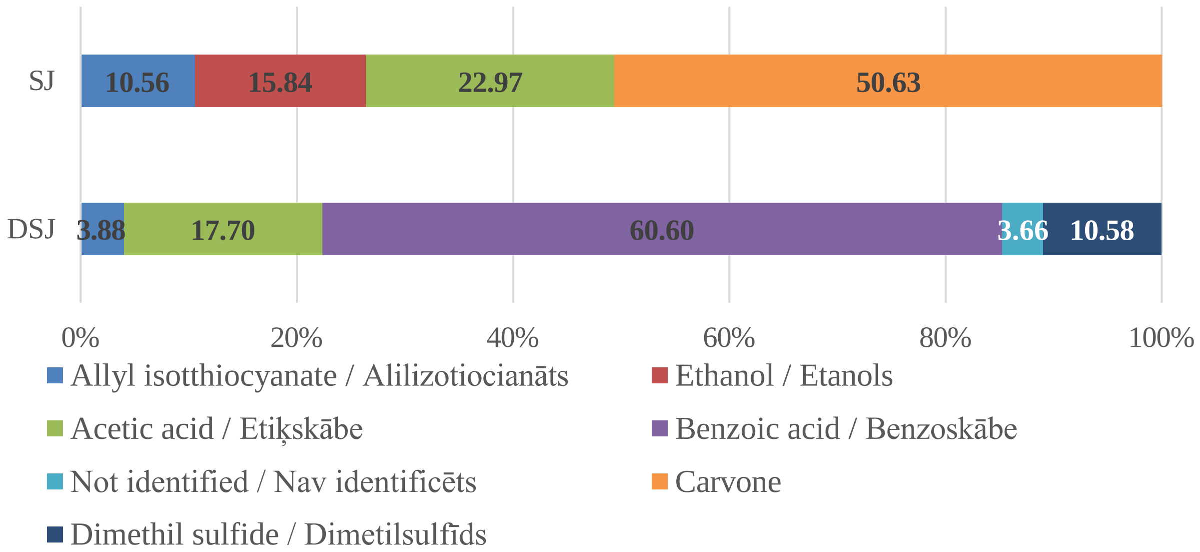

Fig. 3.13. **The percentage of volatile compound peak areas in sauerkraut and dehydrated sauerkraut juice, % /**
3.13. att. Gaistošo savienojumu procentuālais daudzums skābētos kāpostos un dehidrētā skābētu kāpostu sulā, %
SJ – sauerkraut juice / *skābētu kāpostu sula*; DSJ – dehydrated sauerkraut juice / *dehidrēta skābētu kāpostu sula*

There were two common compounds in sauerkraut juice before and after spray-drying – acetic acid with a sour, and allyl isothiocyanate with a pungent taste of mustard, horseradish and wasabi. The metabolised products of glucosinolates - isothiocyanates are the prime sources of the characteristic flavour of the *Brassica* vegetables (Satora et al., 2021; Wieczorek & Drabińska, 2022). The highest peak area in sauerkraut juice was carvone with a caraway and spearmint-like odour, while for dehydrated sauerkraut juice it was benzoic acid with a faint, pleasant odour. Other compounds are characteristic to each of the raw materials.

TPC bioaccessibility of sauerkraut juice and dehydrated sauerkraut juice / *TPC biopieejamība skābētu kāpostu sulā un dehidrētā skābētu kāpostu sulā*

Bioaccessibility (BAC) is defined as a share of bioactive compounds that is released from the food matrix and becomes available for absorption after ingestion (Tchabo et al., 2022). Bioaccessibility of polyphenols is calculated as equality of the analyses after the GIT against the analyses before GIT. The bioaccessibility is considered as high if the BAC index is higher than 1 (Wieca et al., 2016).

For both analysed products – SJ and DSJ, the bioaccessibility index based on antiradical activity by $ABTS^+$ exceeds 1.2 and is considered as high, as shown in Figure 3.14.

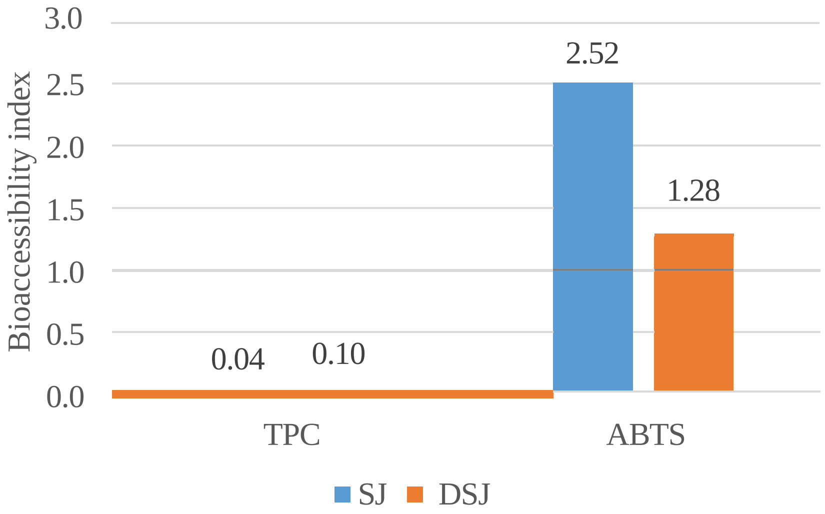

Fig. 3.14**. Bioaccessibility index (BAC) of the sauerkraut juice (SJ) and dehydrated sauer-kraut juice (DSJ) based on TPC and $ABTS^+$ scavenging activity after in vitro digestion /**
3.14. att. Skābētu kāpostu sulas (SJ) un dehidrētas skābētu kāpostu sulas (DSJ) bioloģiskās pieejamības indekss (BAC), pamatojoties uz TPC un $ABTS^+$ aktivitāti pēc sagremošanas in vitro

The bioaccessibility based on TPC is very low for SJ and DSJ and is below 0.2. This can be explained by the compound interaction with gastric juices and enzymes as well as the carrier agent or the combination of several, which plays an important role in the release of the phenolic compounds in the simulated gastrointestinal tract (Jafari et al., 2023).

The bioaccessibility of TPC is complex (Herranz et al., 2019; Tchabo et al., 2022; Iqbal et al., 2023), it is influenced by many factors and depends on a diversity of plant polyphenols, the interaction of compounds, and demeanor in the digestive system (Cantele et al., 2020.; Miedzianka et al., 2022) where the gut microbiota's hydrolytic activity can increase activity and bioavailability of polyphenols (Tuohy et al., 2012).

Bioaccessibility is also affected by the choice of the carrier agent. Dehydrated sauerkraut juice was acquired via spray-drying and starch solution was used as a carrier agent. The choice and combination of carrier agents is crucial, as the desired release of the bioactive compounds, and the interaction of the food matrix it is applied to (Glube et al., 2013; Draijer et al., 2016). Not only these, but several more factors influence the bioaccessibility of the TPC. Furthermore, Cantele (Cantele et al., 2020) have concluded that the absorption of phenols from the solid food matrices is more challenging, as opposed to liquid matrices, because, first they need to undergo mechanical, chemical and enzymatic processes, whereas phenols from the liquid matrices are available straight away.

As Flores (Flores et al., 2013) have investigated in their study about micro-encapsulated blueberry anthocyanins during in vitro with two types of carrier agents – whey protein and gum arabic, that most of the whey protein microcapsules phenolic compounds are degraded in the intestinal digestion, whereas gum arabic, being a complex heteropolysaccharide remains minimally digested. As well as the stability of total phenol content is higher in the gastric phase yet it decreases in the small in-testine, because of bile (Iqbal et al., 2022) (especially phenolic acids) or the compounds transform into other compounds during digestion (Gao et al., 2022; Hurst et al., 2022; Tchabo et al., 2022). Also, encapsulated ascorbic acid in enzyme-hydrolyzed starch (Leyva-López et al., 2019) and rutin in debranched lentil starch coating material is released in the intestinal digestion phase (Ren et al., 2021).

Summary of Chapter 3.3. / *3.3. nodaļas kopsavilkums*

In the horizontally spray-dried sauerkraut juice (DSJ) NaCl content ranged from 8.70 to 14.31 g 100 g^{-1}, and the product could potentially be used as a salt substitute. The obtained results show better total phenol content and antiradical activity in the samples dried with no carrier agent, also the lactic acid bacteria count is higher in 4MD0 samples. The presence of maltodextrin (MD) affected the moisture content and solubility of DSJ, but MD was considered suitable for further use in food production. The study used two extraction methods to determine total phenol content (TPC) and antiradical activity in DSJ and found a moderate to strong correlation between them, indicating that TPC reflects antiradical activity. The organic acid profile of sauerkraut juice was also affected by the maltodextrin concentration, with oxalic, lactic, acetic, and quinic acids being the major organic acids identified.

The study aimed to find the optimal drying parameters for dehydrating juice on a vertical spray-dryer. Different drying parameters and carriers were tested using pasteurised juice, sauerkraut juice of two varieties 'Selma' and 'Kiloplons', and various ratios of starch solution to sauerkraut juice. The results showed that a ratio of 75:50 (starch solution to sauerkraut juice) was optimal for dehydrating sauerkraut juice.

The study used water extraction to determine TPC and antiradical activity for vertically spray-dried sauerkraut juice with different carrying agents. Samples spray-dried with starch solution showed higher TPC and antiradical activity than those with a mixture of maltodextrin and starch solution. Maltodextrin can bind to antioxidants, causing them to become less effective. The moisture content is higher in samples dried with starch solution, which may affect the stability and content of active compounds. DSJ contains a significant amount of minerals and vitamins, with potassium being the most abundant. The spray-drying process is gentle for vitamin C, and the amount remained in the samples was 98 mg 100 g^{-1}.

Sauerkraut juice and its products contain various volatile compounds that contribute to their distinct flavour and aroma. Benzoic acid with faint, pleasant odour, acetic acid with a sour, and allyl isothiocyanate with a pungent taste of mustard, horseradish and wasabi being the most common. Isothiocyanates, the metabolised products of glucosinolates, are the prime sources of the characteristic flavour of *Brassica* vegetables. Carvone and benzoic acid were the compounds with the highest peak area in sauerkraut juice and dehydrated sauerkraut juice, respectively.

The bioaccessibility of polyphenols, including those found in sauerkraut juice, is influenced by factors such as compound interactions with gastric juices and enzymes, the carrier used, and the presence of gut microbiota. The bioaccessibility of TPC is considered low in sauerkraut juice, possibly due to these factors. The choice and combination of carriers used to deliver bioactive compounds is important for achieving desired release and interaction with the food matrix. The stability of TPC varies during digestion, with some compounds being transformed into others or degraded. Encapsulation of bioactive compounds in carrier materials can affect their bioaccessibility and release in the digestive system.

Šajā posmā skābētu kāpostu sula tika kaltēta ar divām kaltēšanas tehnoloģijām – horizontālo un vertikālo izsmidzināšanas kalti. Horizontāli izsmidzinātajā skābētu kāpostu sulā (DSJ) NaCl saturs bija robežās no 8,70 līdz 14,31 g 100 g^{-1}, un produktu, potenciāli, varētu izmantot kā sāls aizstājēju. Iegūtie rezultāti liecina par labāku kopējo fenolu saturu un antiradikālo aktivitāti paraugos, kas kaltēti bez nesējvielas, arī pienskābes baktēriju skaits ir augstāks 4MD0 paraugos. Maltodekstrīna (MD) klātbūtne ietekmēja DSJ mitruma saturu un šķīdību, tomēr izmēģinājuma testi ar DSJ MD izmantošanu pārtikā tika turpināti. Pētījumā tika izmantotas divas ekstrakcijas metodes, lai noteiktu kopējo fenolu saturu (TPC) un antiradikālo aktivitāti DSJ, un konstatēja vidēju līdz spēcīgu korelāciju starp tām, norādot, ka TPC *atspoguļo antiradikālo aktivitāti. Maltodekstrīna koncentrācija ietekmēja arī skābētu kāpostu sulas organisko skābju profilu. Galvenās identificētās organiskās skābes bija skābeņskābe, pienskābe, etiķskābe un hinskābe.*

Pētījuma mērķis bija atrast optimālos kaltēšanas parametrus skābētu kāpostu sulas dehidrēšanai arī vertikālā izsmidzināšanas kaltē. Dažādi kaltes parametri un nesējvielas tika testētas, izmantojot industriālo paraugu un divu šķirņu "Selma" un "Kiloplons" skābētu kāpostu sulu. Rezultāti liecināja, ka cietes šķīdums kā nesējviela un attiecība 75:50 (cietes šķīdums: skābētu kāpostu sula) ir optimāla, lai dehidrētu skābētu kāpostu sulu. Tika testēts arī cietes šķīduma un MD maisījums kā nesējviela.

Pētījumā tika izmantota ūdens ekstrakcija, lai noteiktu TPC un antiradikālo aktivitāti vertikāli izsmidzinātai skābētu kāpostu sulai ar cietes šķīdumu un cietes šķīduma maisījumu ar MD. Paraugi, kas kaltēti ar cietes šķīdumu, uzrāda augstāku TPC un antiradikālo aktivitāti, salīdzinot ar tiem, kuri kaltēti ar maltodekstrīna un cietes šķīduma maisījumu. Maltodekstrīns var saistīties ar antioksidantiem, samazinot to efektivitāti. Paraugos, kas kaltēti ar cietes šķīdumu, mitruma saturs ir augstāks, un tas var ietekmēt aktīvo savienojumu stabilitāti un saturu. DSJ satur ievērojamu minerālvielu un vitamīnu daudzumu, un kālijs ir visbagātīgākais. Izsmidzināšanas kaltēšana ir bijusi saudzīga attiecībā uz C vitamīnu, un paraugā ir saglabājies 98 mg 100 g^{-1}.

Visbiežāk sastopamie gaistošie savienojumi skābētu kāpostu sulā un tās produktos, kas piešķir īpašo aromātu, bija benzoskābe ar vieglu, patīkamu smaržu, etiķskābe, un alilizotiocianāts ar sīvu sinepju, mārrutku un vasabi garšu. Brassica dārzeņu raksturīgo garšu nodrošina izotiocianāti, glikozinolātu metabolizētie produkti. Karvons un benzoskābe bija savienojumi ar augstāko pīķa laukumu attiecīgi skābētu kāpostu sulā un dehidrātā.

Polifenolu biopieejamību ietekmē tādi faktori kā mijiedarbība ar kuņģa sulām un fermentiem, izmantotā nesējviela un zarnu mikrobioms. Iespējams, minēto faktoru dēļ, TPC biopieejamību skābētu kāpostu sulā uzskata par zemu. Izmantoto nesējvielu izvēle un to kombinācija ir svarīga, lai bioaktīvo savienojumu piegādē panāktu vēlamo izdalīšanos un mijiedarbību ar izejvielu. TPC stabilitāte fermentācijas laikā ir atšķirīga, daži savienojumi pārveidojas par citiem vai sadalās. Bioaktīvo savienojumu iekapsulēšana nesējvielā var ietekmēt to biopieejamību un izdalīšanos gremošanas sistēmā.

3.4. Sauerkraut juice products in food applications / *Skābētu kāpostu sulas produktu izmantošana pārtikā*

There were various tests conducted at the Latvia University of Life Sciences and Technologies to find appropriate sauerkraut juice product applications in food. The experiments involved testing the sauerkraut juice in various food products such as dry soup mixes, soup paste, marinade for meat, minced meat, tomato juice, and cottage cheese. Experiments with tomato juice and cottage cheese gave a bald taste, as the sourness of these products overwhelms the sauerkraut juice. However, the use of spice mixes with sauerkraut juice for meat, French fries, or chips appears to be a promising avenue for future research and possible project development.

The results showed that the dry soup mixes experimentally prepared had a bitter and flat flavour, while the soup paste with concentrated sauerkraut juice was tasteful and showed promise for further research. The use of concentrated sauerkraut juice as marinade for pork belly and minced meat tenderised and aromatized the experimental meat samples. A five-point hedonic scale sensory evaluation was carried out, to clarify the overall liking, taste, smell and texture preferences of the meat samples and results are shown in Figure 3.15.

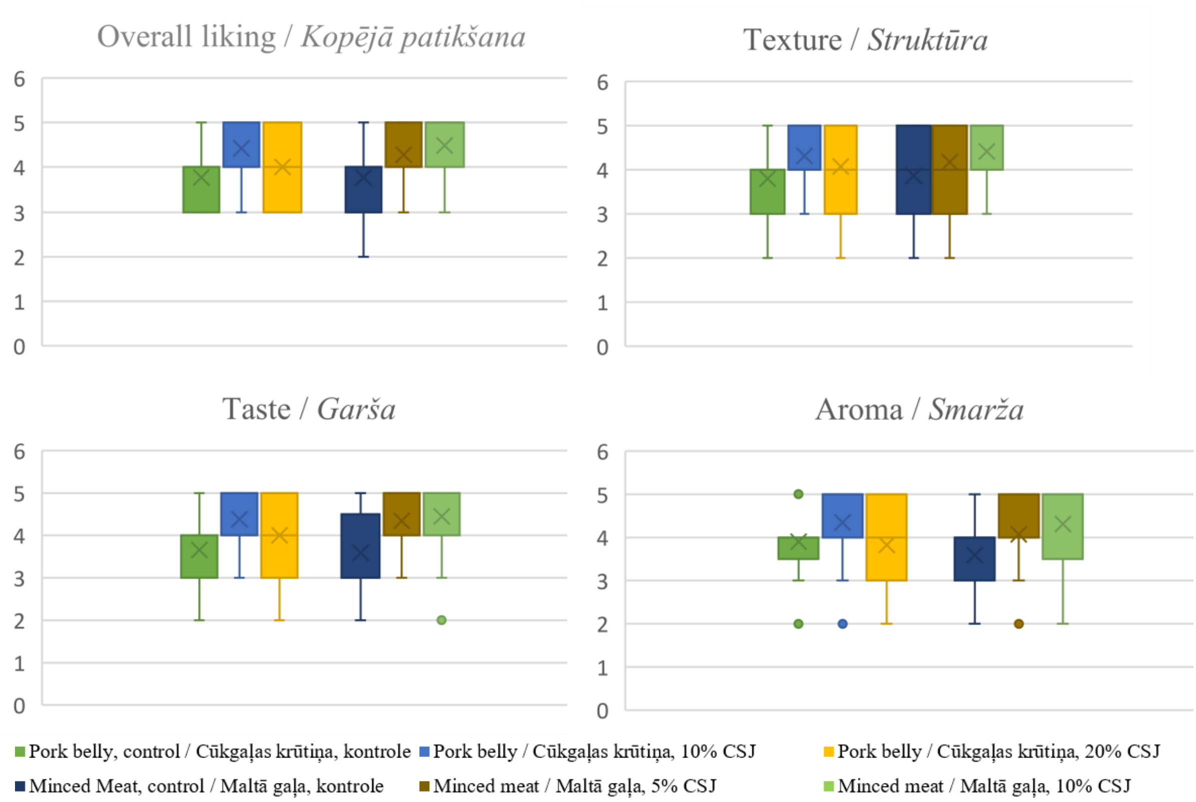

Fig. 3.15. **Hedonic evaluation of the experimental meat samples – pork belly and minced meat /**
3.15. att. Eksperimentālo gaļas paraugu, cūkgaļas krūtiņas un maltās gaļas, vērtēšana pēc hedoniskās skalas

No other research was carried out for these products at this stage.

The overall liking of the experimental meat samples, pork belly and minced meat were rated the highest with addition of 10% CSJ. Also, the taste preferences, aroma and texture were rated the highest in these samples.

3.4.1. Experimental salad dressings / *Eksperimentālās salātu mērces*

Vertically spray-dried sauerkraut juice, variety 'Kiloplons' with a starch solution as a carrier agent, was tested in salad dressings as a salt alternative since NaCl content in DSJ is 12%, and in addition, has sweet and sour taste nuances.

To choose the experimental amount of salt and DSJ, commercially available dressings were investigated. The variation of salt content is significant, as shown in Table 3.18.

The highest salt content was in 'Spilva''s produced salad dressings - 2.2 – 2.6 g 100 g^{-1} and garlic sauce 2 g 100 g^{-1}, while 'Kraft' balsamic vinaigrette had a 1 g of salt and 'Heinz' garlic sauce 1.3 g of salt 100 g^{-1}.

Most of the other components were in common in salad dressings and garlic sauces. The differences between the salad dressings and garlic sauces tested were primarily in the choice of ingredients, such as sunflower or rapeseed oil, and the inclusion of milk or yogurt powder.

Table 3.18. / *3.18. tabula*

Salt content and energy value in commercially available dressings /

Mazumtirdzniecībā pieejamo komerciālo mērču enerģētiskā vērtība un sāls saturs

With olive oil / *Komerciālie paraugi ar olīveļļu*	**NaCl, g 100 g⁻¹**	**Energy value /** *Enerģētiskā vērtība*, **kcal**
Kraft balsamic vinaigrette	1	219
Oak'a Burger, garden salad dressing	1.8	167
Oak'a Burger, balsamico dressing	1.8	182
Spilva salad dressing	2.2	30
Spilva lemon/olive oil dressing	2.6	50
With garlic/ *Komerciālie paraugi ar ķiploku*	**NaCl, g 100 g⁻¹**	**Energy value /** *Enerģētiskā vērtība*, **kcal**
Heinz garlic	1.3	371
Hellmann's garlic	1.5	283
Taste Me garlic	1.9	405
Kitchen masters garlic sauce	1.9	405
Spilva garlic sauce	2	285

The salad dressings consisted of water, vinegar, olive oil (or soybean/canola oil), sugar, salt, spices, stabilisers, and preservatives, while the garlic sauces contained water, sugar, sunflower or rapeseed oil, modified maize or starch, egg yolk powder with maltodextrin, milk/whey/yogurt powder, garlic (at concentrations of 0.5%, 0.7%, or 5%), garlic-chives mixture (11%), parsley, mustard, chives, vinegar (citric, malic, ascorbic, or lactic acid), thickeners (xanthan or guar gum), preservatives (potassium sorbate, sorbic acid, or sodium benzoate), flavourings, and antioxidants.The dispersion of salt and sugar content in commercially available dressings is shown in Figure 3.16.

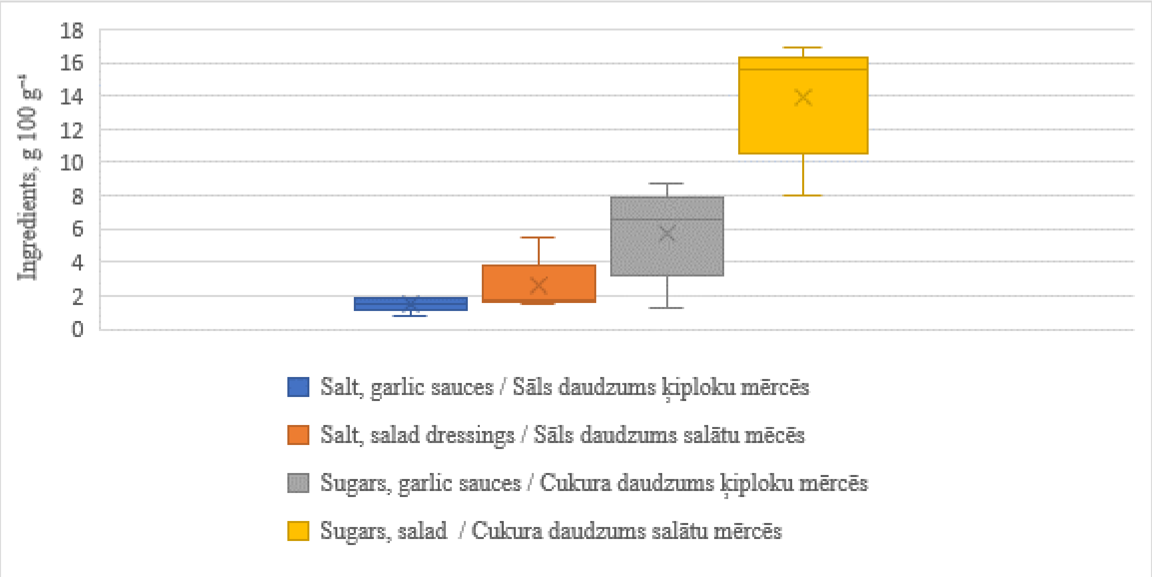

Fig. 3.16. **Average salt and sugar content in the commercially available salad dressings and garlic sauces /**

3.16. att. Sāls un cukura daudzums salātu un ķiploku mērcēs

.

To avoid potential interactions with other ingredients, the experimental dressings were prepared using only dehydrated sauerkraut juice (DSJ) and either olive oil or sour cream. The DSJ amount used and salt equivalent is described in section 2.3.4. Table 2.3.

In the descriptive sensory evaluation of experimental salad dressings, there were 11 flavours mentioned or identified: sweet, salty, sour, bitter, spicy, garlic, cabbage, yogurt, mayonnaise, cottage cheese, and vinegar. Based on these 11 taste attributes, a RATA – rate-all-that-apply taste and aftertaste intensity tests were carried out.

Experimental dressing samples with <u>olive oil</u> / *Eksperimentālie paraugi ar alīveļļu*

<u>Frequency of taste attributes</u>

The panels highlighted the prevalence of bitter taste in dressing samples made with the addition of olive oil (Table 3.19). The bitterness of these samples can be explained by adding fresh olive (virgin) oil to DSJ with a typical bitter taste due to polyphenols availability (tannins in particular).

Table 3.19. / *3.19. tabula*

Frequency of terms used to describe the taste of dressing sample with olive oil /
Biežāk atzīmētie termini eksperimentāliem paraugiem ar olīveļļu

Samples / *Paraugi*, **%**	**sweet /** *salds*	**sour /** *skābs*	**salty /** *sāļš*	**bitter /** *rūgts*	**spicy /** *pikants*	**garlic /** *ķiploks*	**cabbage** */ kāposts*
	T/AT	T/AT	T/AT	T/AT	T/AT	T/AT	T/AT
OOC	80/43	77/37	83/43	73/63	40/37	23/13	20/3
OO1	70/53	93/43	100/73	67/77	53/63	73/47	47/30
OO2	67/37	100/60	97/67	73/57	40/53	50/30	43/30
OO3	63/50	80/47	93/67	67/47	50/43	37/30	17/23

*T – taste / *garša*; AT – aftertaste / *pēcgarša*

OOC – experimental dressing sample with olive oil, control / *eksperimentālais paraugs ar olīveļļu, kontrole;* OO1, OO2, OO3 - experimental dressing sample with olive oil and different dehydrated sauerkraut juice concentration / *eksperimentālais paraugs ar olīveļļu un dehidrētu skābētu kāpostu sulu, dažādās koncentrācijās*

Salty taste in the control sample (OOC, 2% of salt) was identified by 63% of participants yet the same taste was identified by 80% in the sample OO1, with the salt equivalent of 2%, and in the samples with the reduced amount of salt (OO2, OO3) - 70%, 73%, which is significantly higher than the control sample. It could be explained that not salt nor DSJ dissolves in oil and is somewhat encapsulated in fat (Noort et al., 2012) and dissolves only in the contact with saliva, creating the 'salty spot' (Beck et al., 2021), meanwhile, DSJ having more taste attributes creates an abundant sensory profile (Gaudette et al., 2019). In the OO1 sample garlic taste was identified by 43% of participants, and 37% in the samples OO2, OO3.

The bitter aftertaste remains in the samples OOC and OO1. The salty taste lingers still in the aftertaste in all of the DSJ samples – more than 43%, while in the control sample 27%, the encapsulation effect lets salty particles dissolve gradually (Noort et al., 2016).

A radar chart in Figure 3.17. displays the intensity (the sum of rated points from 1 to 5) of the 11 taste attributes.

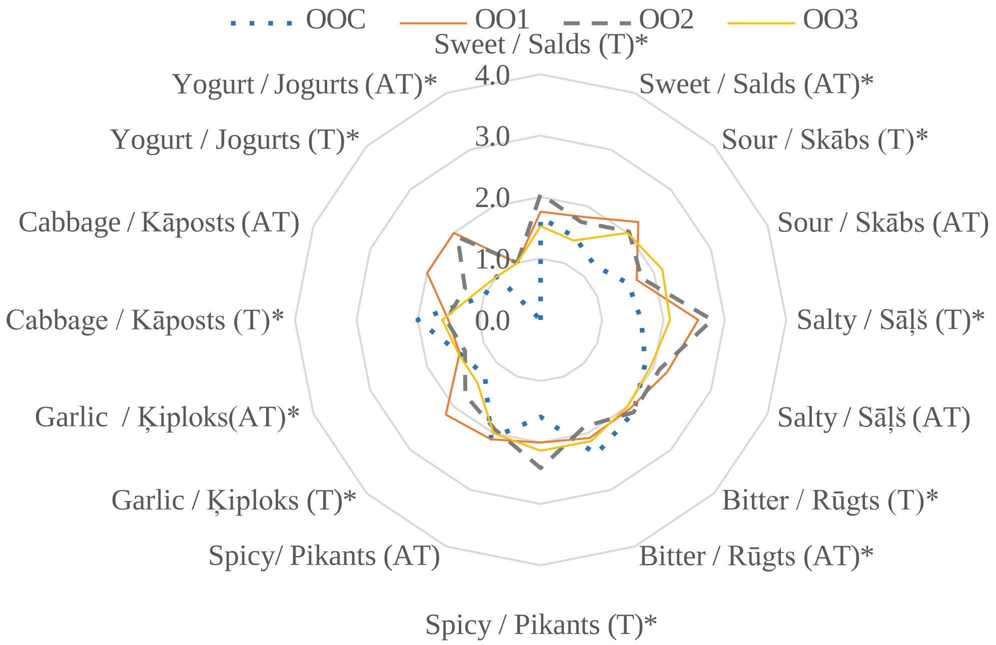

Fig. 3. 17 **The intensity of taste (T) and aftertaste (AT) in the experimental dressing samples with olive oil /** *3.17. att. Garšas (T) un pēcgaršas (AT) intensitāte eksperimentālajos paraugos ar olīveļļu*

**represent significant differences (p<0.05)*

OOC – experimental dressing sample with olive oil, control / *eksperimentālais paraugs ar olīveļļu, kontrole;* OO1, OO2, OO3 - experimental dressing sample with olive oil and different dehydrated sauerkraut juice concentration / *eksperimentālais paraugs ar olīveļļu un dehidrētu skābētu kāpostu sulu, dažādās koncentrācijās*

The intensity of salty taste is significantly stronger in the samples with DSJ, though it is salt equivalent in OO1 and reduced amount of NaCl in samples OO2, OO3. Also, the sour taste is intense followed by bitter and garlic.

The intensity of the aftertaste fades. Bitter taste lingers longer in the control sample OOC, while salty and spicy lingers in the samples with DSJ.

The transcript of volatile compounds in the experimental dressings with olive oil

There were four chemical groups represented in the samples with olive oil – aldehydes, esters, alcohols and acids, in total 11 volatile compounds with the highest peak areas, exceeding 5%, are presented Table 3.20.

Acetic acid with sour odour was the most predominant in the samples with DSJ, reducing accordingly to the amount of added DSJ. The addition of DSJ diminishes the volatile compound peak areas and are significantly less than in the control sample, which can be favourable because of the specific cabbage aroma. The control sample presents all the volatile compounds that are characteristic to most olive oils (Oğraş et al., 2018). In general, the odour of the samples is grassy, leafy green, with a slight sweetness and fruity sharpness.

Table 3.20. / *3.20. tabula.*

The transcript of identified volatile compounds in the samples with olive oil, % / *Gaistošie savienojumi un to atšifrējums paraugos ar olīveļļu*, %

Volatile compound / *Gaistošie savienojumi*	**OC**	**OO1**	**OO2**	**OO3**	**Aroma characteristics /** *Aromātu raksturojums*
Aldehydes / *Aldehīdi*					
2-hexanal / *2- heksanāls*	12.28	3.69	5.69	4.30	Leaf, green / *zaļu lapu*

Continuation of the table 3.20.
3.20. tabulas turpinājums

Volatile compound / *Gaistošie savienojumi*	**OC**	**OO1**	**OO2**	**OO3**	**Aroma characteristics /** *Aromātu raksturojums*
Benzaldehyde / *benzaldehīds*	6.49	0.44	1.85	0.82	Almond, burned sugar / *mandeļu, dedzināta cukura*
Esters / *Esteri*					
3 hexen-1ol, acetate (E) / *3-heksēn-1ols, acetāts*	9.88	4.83	6.93	4.50	Sharp fruity green aroma reminiscent of unripe pear or banana / *ass, negatavu augļu, bumbieru vai banānu*
Alcohols / *Spirti*					
hexen-1ol / *heksēn-1ols*	6.77	2.90	3.83	1.73	Grassy green aroma / *zaļas zāles*
3,7,11 trimethyl-1-dodecanol / *3,7,11 trimetil-1-dodecanols*	-	-	-	3.21	
benzyl alcohol / *benzillspirts*	17.20	0.73	2.34	1.66	Sweet, flower / *salds, ziedu*
ni	11.03	-	-	-	
Acids / *Skābes*					
Acetic acid / *etiķskābe*	18.51	84.37	75.19	50.14	Sour / *skābs*
Pentanoic acid / *pentānskābe*	2.70	0.56	0.39	-	Sweet / *salds*
n-decanoic acid / *n-dekānskābe*	1.26	0.87	0.85	3.64	Rancid, fat / *sasmacis, taukains*

ni – not identified / *nav identificēts*
OOC – experimental dressing sample with olive oil, control / *eksperimentālais paraugs ar olīveļļu, kontrole;* OO1, OO2, OO3 - experimental dressing sample with olive oil and different dehydrated sauerkraut juice concentration / *eksperimentālais paraugs ar olīveļļu un dehidrētu skābētu kāpostu sulu, dažādās koncentrācijās*

Experimental dressing samples with sour cream / *Eksperimentālie paraugi ar skābo krējumu*

Frequency of taste attributes

Sour and salty tastes were identified by the most participants in the samples with sour cream, as shown in Table 21. Salty taste was equally rated in the control sample SCC and sample with salt equivalent SC1, and so was the sour taste. All of the samples were rated as yogurt-like and in SC1 and SC2 samples a mayonnaise taste was identified. Interestingly enough, also in the samples with sour cream a garlic taste was identified, just like in the olive oil sample, with the highest DSJ addition.

Aftertaste is characterised with the sour taste. The salty taste in the aftertaste is felt significantly higher in the samples SC1 and SC2. The sweet aftertaste in the control sample is felt by more participants than in the initial taste.

Table 3.21. / *3.21. tabula*

Frequency of terms used to describe the taste of dressing sample with sour cream / *Biežāk atzīmētie termini eksperimentāliem paraugiem ar skābo krējumu*

Samples / *Paraugi*, %	**sweet / *salds***	**sour / *skābs***	**salty / *sāļš***	**bitter / *rūgts***	**spicy / *pikants***	**garlic / *ķiploks***	**cabbage / *kāposts***	**yogurt / *jogurts***	**mayonnaise / *majonēze***	**cottage cheese / *biezpiens***	**vinegar / *etiķis***
	T/AT	T/AT	T/AT	T/AT	T/AT	T/AT	T/AT	T/AT	T/AT	T/AT	T/AT
SCC	50/57	87/67	93/57	27/20	33/30	37/20	27/10	50/33	47/47	30/50	23/0
SC1	67/50	87/70	93/80	30/17	43/27	60/40	43/33	63/50	60/57	43/50	40/13
SC2	60/43	80/63	77/67	30/20	37/23	67/43	47/23	57/40	57/50	40/30	47/7
SC3	73/50	77/63	60/43	27/17	47/27	40/27	33/20	60/40	43/30	43/33	23/3

*T – taste / *garša*; AT – aftertaste / *pēcgarša*
SCC – experimental dressing sample with sour cream, control / *eksperimentālais paraugs ar skābo krējumu, kontrole*; SC1, SC2, SC3 - experimental dressing sample with sour cream and different dehydrated sauerkraut juice concentration / *eksperimentālais paraugs ar skābo krējumu un dehidrētu skābētu kāpostu sulu, dažādās koncentrācijās*

A radar chart in Figure 3.18. displays the intensity (the sum of rated points from 1 to 5) of the 11 taste attributes in the experimental dressings with sour cream.

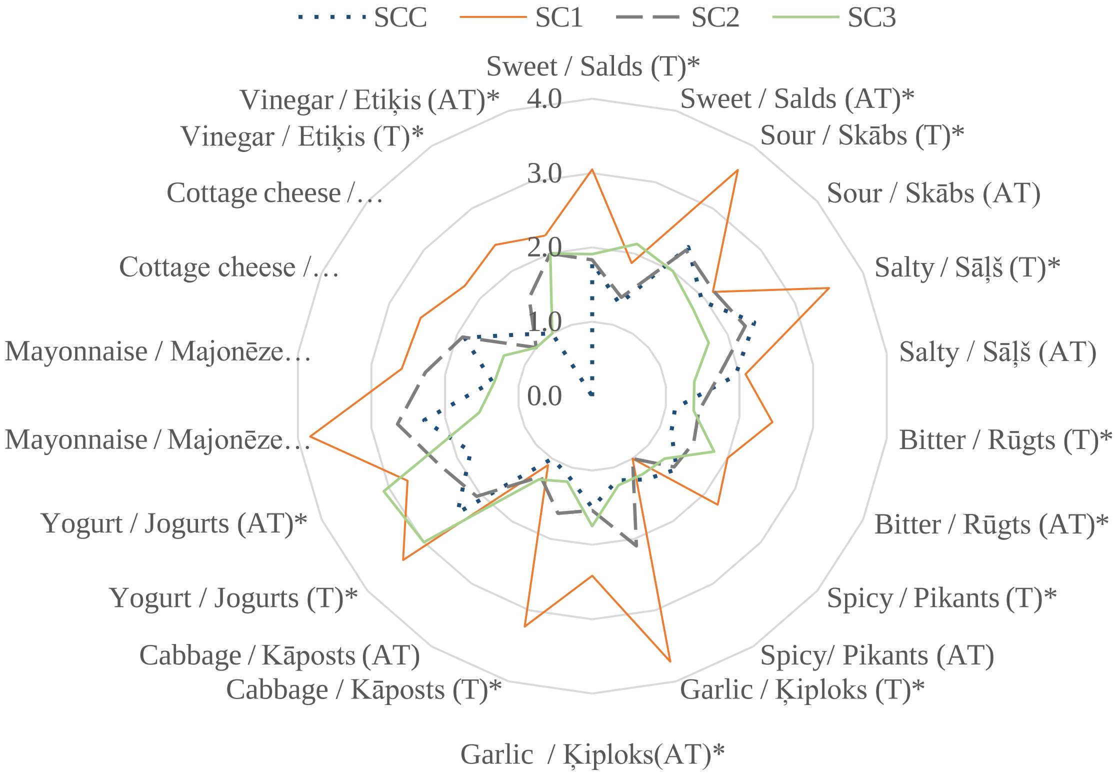

Fig. 3.18. **The intensity of taste (T) and aftertaste (AT) attributes in the experimental samples with sour cream /** *3.18 att. Garšas (T) un pēcgaršas (AT) intensitāte eksperimentālajos paraugos ar skābo krējumu*

*represent significant differences ($p < 0.05$)

SCC – experimental dressing sample with sour cream, control / *eksperimentālais paraugs ar skābo krējumu, kontrole*; SC1, SC2, SC3 - experimental dressing sample with sour cream and different dehydrated sauerkraut juice concentration / *eksperimentālais paraugs ar skābo krējumu un dehidrētu skābētu kāpostu sulu, dažādās koncentrācijās*

The most intensive taste is in the SC1 sample with the highest DSJ amount, with the predominant sour and salty tastes but also garlic, mayonnaise and yogurt. All of the samples (except the control SCC and OOC) are made with sour cream and dehydrated sauerkraut juice. The intensity of taste in all of the other samples are with no significant differences, representing sour and salty with a hint of yogurt, especially in the SC3 sample, and mayonnaise.

The aftertaste is not very intense but varies greatly. For SC1 and SC3 samples, the tastes in the aftertaste are the same – sour, salty, mayonnaise, yogurt and garlic. In the sample SC2, the garlic taste lingers in the aftertaste. While the control sample SCC with fine salt addition has a sweet, sour, salty, mayonnaise and cottage cheese aftertaste.

The transcript of volatile compounds in the experimental dressings with sour cream

In total there were 17 volatile compounds identified with the highest peak areas exceeding 5% present in Table 3.22.

Table 3.22. / *3.22. tabula*

The transcript of identified volatile compounds in the samples with sour cream, % /
Gaistošie savienojumi un to atšifrējums paraugos ar krējumu, %

Volatile compound / *Gaistošie savienojumi*	**SCC**	**SC1**	**SC2**	**SC3**	**Aroma characteristics /** *Aromātu raksturojums*
Aldehydes/ *Aldehīdi* **Ketones /** *Ketoni*					
1,1-Dimethyl hydrazine / *1,1-dimetilhidrazīns*		33.44		27.92	
1,4-Difluoro, 1,3-butadiyne / *1,4-difluors, 1,3-butadiīns*		3.86	7.26	4.19	Ammonia-like / *amonijam līdzīgs*
Esters / *Esteri*					
3-Hydroxy, 2-butanone / *3-hidroksi, 2-butanons*	5.26			2.54	
1,3-Dioxol-2-one / *1,3-dioksol-2-ons*	7.99				Buttery odour / *sviestains aromāts*
Alcohols */ Spirti*					
Benzyl alcohol / *Benzilspirts*			1.36	0.34	Sweet, flower / *salds, puķu*
1,2-Diphenyl-,1,2-ethanediol/ *1,2-difenil-,1,2-etāndiols*		1.63			
Acids / *Skābes*					
1-Naphthalenecarboxylic acid, 8-bromo / *1-naftalīnkarbonskābe, 8-broms*			1.63		Strong lemon odour / *Spēcīga citrona smarža*
Acetic acid / *Etiķskābe*	42.98	33.44	44.33	27.92	Sour / *Skābs*
Butanoic acid / *Butānskābe*	18.07	12.26	18.64	12.70	Rancid, cheese, sweet/ *Sasmacis, siers, salds*

Continuation of the table 3.22.
3.22. tabulas turpinājums

Volatile compound / *Gaistošie savienojumi*	**SCC**	**SC1**	**SC2**	**SC 3**	**Aroma characteristics** */ Aromātu raksturojums*
Octanoic acid / *Oktānskābe*	5.98	1.50	2.36	1.58	Sweet, cheese / *salds, siers*
N-decanoic acid / *N-dekānskābe*		1.49		1.05	Rancid, fat / *sasmacis, tauki*
Nonanoic acid / *Nonanoskābe*			1.94		Waxy, dirty cheese, cultured dairy / *Vaskains, sierains, raudzēti piena produkti*
Heterocyclic compounds / *Heterocikliskie savienojumi*					
Methyl Arsine dibromide / *Metilarsīna dibromīds*				8.85	Pungent, acid-like
Morpholine / *Morfolins*		2.37	4.09		Fishy, amine / *Asa, līdzīga skābei,zivs, amīns*
2-(2-Propenyl)-furan / *2-(2-propenil)furāns*	5.57				

SCC – experimental dressing sample with sour cream, control */ eksperimentālais paraugs ar skābo krējumu, kontrole*; SC1, SC2, SC3 - experimental dressing sample with sour cream and different dehydrated sauerkraut juice concentration / *eksperimentālais paraugs ar skābo krējumu un dehidrētu skābētu kāpostu sulu, dažādās koncentrācijās*

Overall liking of the experimental dressing samples

There were significant ($p<0.05$) differences among the samples when rating overall acceptability, either in oil or sour cream samples, as shown in Figure 3.19. The liking of these samples was ranked from 1 – 5: 1 - do not particularly like; 5 - like the most. The overall liking of olive oil samples, OO1 and OO2, with an DSJ salt equivalent of 2 and 1.5% were liked the most, and the sample with a reduced amount of salt (OO3 - 1.0% salt equivalent) was liked more than the control sample, but with no significant differences. There were significant ($p<0.05$) differences between the sour cream samples. For SC1, there was no rating of 5 (like the most), and in total, among the samples with the DSJ, most participants liked these samples the least, which may be explained by their strong taste intensity. The sample SC3 (reduced amount of salt with least DSJ) was as liked as SC1.This could be explained by quite the opposite reason, due to not enough taste intensity. However, the average liking was rated more than 3 in both samples, compared with SCC. SC2, with a 0.5% salt equivalent, was liked the most, being described as not too salty and with the most taste variation. Despite the differences in the SJP salt equivalent, all of the samples were liked more than the SCC, leading to the conclusion that sauerkraut juice powder could be used as an alternative to salt.

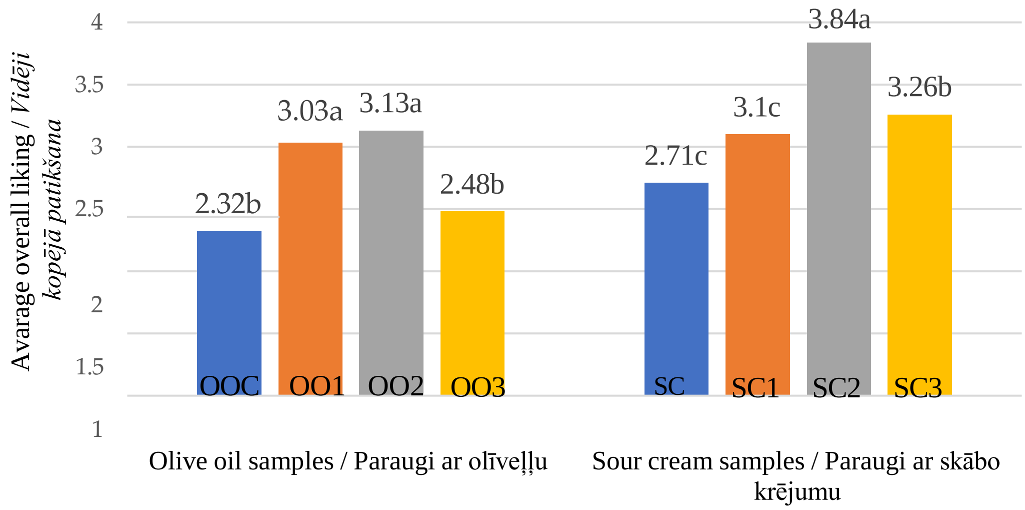

Fig. 3.19. **Overall liking of the experimental dressing samples /**
3.19 att. Eksperimentālo mērču paraugu kopējā patikšana

OOC – experimental dressing sample with olive oil, control / *eksperimentālais paraugs ar olīveļļu, kontrole*; OO1, OO2, OO3 - experimental dressing sample with olive oil and different dehydrated sauerkraut juice concentration / *eksperimentālais paraugs ar olīveļļu un dehidrētu skābētu kāpostu sulu, dažādās koncentrācijās* SCC – experimental dressing sample with sour cream, control / *eksperimentālais paraugs ar skābo krējumu, kontrole*; SC1, SC2, SC3 - experimental dressing sample with sour cream and different dehydrated sauerkraut juice concentration / *eksperimentālais paraugs ar skābo krējumu un dehidrētu skābētu kāpostu sulu, dažādās koncentrācijās*

3.4.2. Dehydrated sauerkraut juice (DSJ) in bread and meat applications and their bioaccessibility / *Skābētu kāpostu sulas pulvera pielietojums maizes un gaļas izstrādājumos un to biopieejamība*

Sauerkraut juice products were tested also in collaboration with the project partners.

Bakery "Flora" – rye bread and crisp bread – both of the sauerkraut products can be used in bread baking but it's important to evaluate the inserted amount to maintain the quality. Also, DSJ can substitute some amount of salt and sugar in the recipe. The results are explained in Appendix 1.

"Margret" Ltd, have tested concentrated sauerkraut juice in 27 meat products – all of them were with negative organoleptic properties, causing mouldy surface, sour taste and were with a shorter best before. The results are explained in Appendix 2.

In order to investigate the actual bioaccessibility of the total phenol compounds (TPC) and the impact of DSJ to the experimental bread and meat samples, they were subjected to *in vitro* gastrointestinal digestion. There are numerous studies on phenolic compound bioaccessibility, mostly because the compounds are considered as low-bioavailable (Iqbal et al., 2022) thus, the potential health benefits are under discussion (Gao et al., 2022; Iqbal et al., 2023).

The bioaccessibility of TPC in wheat-based food matrices is different from that in meat-based products. Wieca (2016) have confirmed that wheat flour contains bound phenolics that are easily released during simulated digestion. The studies of meat protein and phenolics action *in vitro* are scarce, to the best of our knowledge, but (Rashidinejad et al., 2017) have investigated that milk proteins bind the phenols and can affect their release due to interaction between them (Draijer et al., 2016). The TPC is affected differently in GIT, depending on the food matrix, its physicochemical characteristics, and its composition (Herranz et al., 2019; Iqbal et al., 2023). When testing poultry feed with the addition of lucerne or chicory, the total phenol content decreased in the gastric phase but increased in the intestinal phase (Iqbal et al., 2022). Also, higher content of bioactive compounds in the food matrix does not always ensure the same results in and after the GIT (Tomsone, etal., 2020), as well as the accessibility of the compounds is influenced by numerous conditions – the complexity of phenolic compounds in food matrix, metabolic pathway etc. (Herranz et al., 2019; Tchabo et al., 2022).

Experimental bread samples

The aim of this experiment was to evaluate, if the addition of DSJ affects the bread quality, and can increase the bioactive compound content and the bioaccessibility in the wheat bread. The results, shown in Table 3.23. represent a significant influence on the total phenol content by the addition of DSJ to the wheat bread. The TPC content and antiradical activity by $ABTS^+$ in the bread DSJ sample is higher by 66% and 56% accordingly. It has been reported before that plant materials and food production by-products added to flour products increase the TPC and antiradical activity (Ahmed & Abozed, 2015; Tomsone, et al., 2020). In our study, supplementing wheat bread with DSJ increases the TPC content in the sample, thus the food matrix provides suitable conditions for the release (or interaction) of the compounds.

Table 3.23. / *3.23. tabula*

Total phenol content and antiradical activity by ABTS+ in the bread samples /
Kopējo fenolu saturs un antiradikālā aktivitāte maizes paraugos

Parameters / *Rādītāji*	**Bread C / *Maizes kontroles paraugs***	**Bread DSJ /** *Maizes paraugs ar DSJ*
TPC, mg 100 g GAE, DW	54.36 ± 1.33a	82.56 ± 0.98b
ABTS, mg TE 100 $^{-1}$, DW	4.61 ± 0.24a	8.23 ± 0.56b

TPC – total phenol content / *kopējais fenolu saturs*
ABTS – antiradical activity / *antiradikālā aktivitāte*
Values with different letters are significantly different / *vērtības ar atšķirīgiem burtiem norāda būtiskas atšķirības* ($p<0.05$)

Although the TPC was higher in the Bread DSJ, the bioaccessibility index BAC, shown in Figure 3.20. is higher in the Bread C - 1.10 while in the DSJ sample it is 0.65. This indicates that the bioaccessibility of the phenolic compounds in wheat bread, are highly bioaccessible, however encapsulation of DSJ may interact with other compounds to form indigestible compounds and does not protect the TPC from the severe environment of the stomach (Tomsone, etal., 2020).

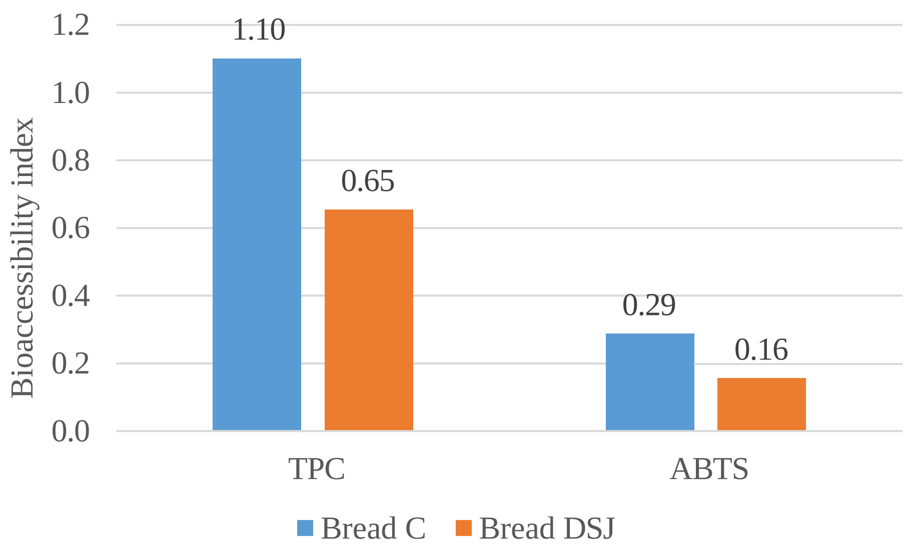

Fig. 3.20. **Bioaccessibility index (BAC) of the bread samples based on TPC and $ABTS^+$ scavenging activity after in vitro digestion /**
3.20. att. Maizes paraugu biopieejamības index (BAC), pamatojoties uz TPC un $ABTS^+$ antiradikālo aktivitāti pēc sagremošanas kuņģa-zarnu trakta simulācijas iekārtā

That is contrary to the bread samples enriched with green coffee (Wieca et al., 2016), where all of the samples were highly bioaccessible *in vitro* but the control sample was even higher than 2. A bioaccessibility score higher than 1 is generally considered as high. The interactions among food matrix, phenolic compounds and GIT enzymes is still under investigation (Tchabo et al., 2022).

Volatile compounds in the bread samples

There were 9 volatile compounds detected in the bread samples, 8 of them exceeded 5 % and are shown in Figure 3.21. Hexanal did not exceed 1% and therefore is not discussed in this study. The highest peak area was for benzaldehyde, giving volatile oil-of-almond odour and it was higher with the DSJ addition., 29.15 % and 33, 60 %, accordingly. A very distinct nuance – a caraway-like odour – in the bread sample with the DSJ addition. There is 1% of caraway added in the production process of sauerkraut in "Dimdiņi" Ltd (Latvia), and this volatile compound is so strong to remain through the spray-drying process and the bread baking. A freshly baked wheat bread, with no caraway or DSJ added, gives a rose like aroma.

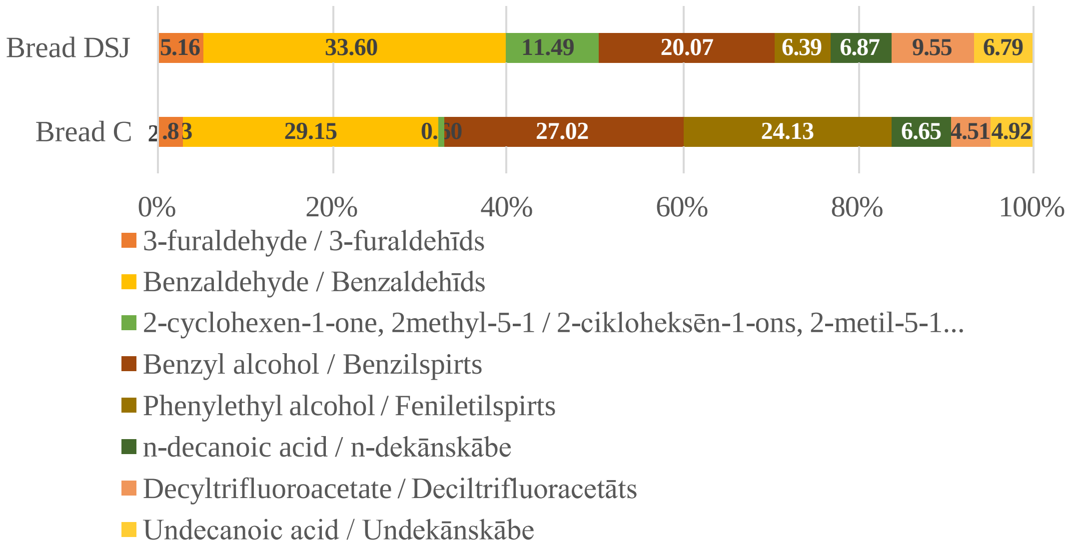

Fig. 3.21. **The percentage of volatile compound peak areas in the bread samples, % /**
3.21. att. Gaistošo savienojumu procentuālais daudzums maizes paraugos, %

A sensory evaluation was carried out for bread with dehydrated sauerkraut juice. 52 participants were invited to rate overall liking, structure, taste and aroma on a 5-point hedonic scale. There are no significant differences in overall liking of Bread C and Bread DSJ, both samples are equally liked, as well as no significant differences are observed in structure, taste and aroma, as shown in Figure 3.22.

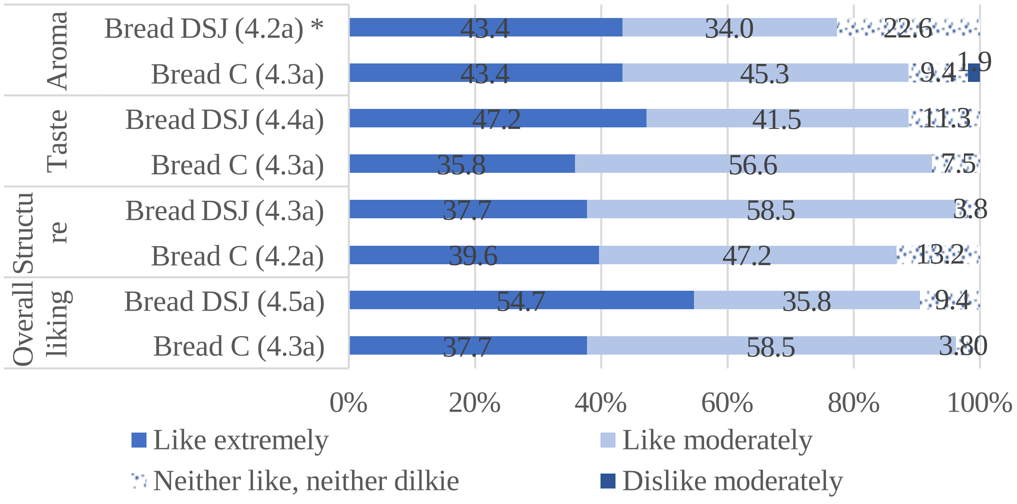

Fig. 3.22. **Hedonic evaluation of the bread samples** /
3.22. att. Maizes paraugu vērtēšana pēc hedoniskās skalas
* Values in brackets present the mean value of hedonic evaluation and the same letter along the values shows that the difference between the means between two samples is not statistically significant.

Other authors discussed that mean in some cases is not representative for hedonic evaluation due to differences in frequency of evaluations (Wichchukit & O'Mahony, 2015). Therefore, in Figure 3.20. is presented frequency of each evaluation in percentages and few trends could be observed. It could be concluded that for overall liking and taste of Bread DSJ more participants selected evaluation like extremely, 54.7% and 47.2% respectively, and it is higher compared to Bread C. More people extremely like bread with DSJ. Also, it could be seen that the aroma of Bread DSJ got 22.6% of evaluation – neither like, nor dislike, showing that the aroma of sample is not preferable for consumers, compared to Bread C.

Experimental meat samples

The addition of plant-based ingredients provides total phenol content in meat products and is influenced by the method used to prepare the meat, such as mincing and heat treatment. Due to the potential interaction of phenols with the meat's chemical composition, which consists of lipids, proteins, and polysaccharides their extractability from the samples can be affected. (Cheng et al., 2018). In our study, the addition of DSJ in the meat samples had a significant impact ($p<0.01$) of on the TPC. The TPC content in the meat DSJ sample was 61.21 ± 1.03 mg 100 g^{-1} GAE, DW and antiradical activity by $ABTS^{+}$ 5.72 ± 0.17 mg TE 100 $^{-1}$, DW.

The bioaccessibility index for TPC of the meat DSJ sample is significantly higher than 1 and thus the compounds are available for absorption. The combination of proteins and phenolic compounds can affect the bioaccessibility of TPC, and is influenced by the specific compound interactions (Draijer et al., 2016.; Miedzianka et al., 2022). As Nagar (2023) has studied, dissolved oxygen levels in the intestinal phase and bile contribute to the decrease in bioaccessibility - the absence of oxygen increases the bioaccessibility of polyphenols.

Volatile compounds in the meat samples

There were 8 volatile compounds detected in meat samples. 7 of them exceeded 5 % and are shown in Figure 3.23. The highest peaks for the Meat C sample were hexanal, mostly formed by oxidation of linoleic acid (Jiang et al., 2022), and 3-furaldehyde, giving fruity, green grass and almond like odour, also volatile oil-of-almond. The highest peaks in Meat DSJ sample were benzaldehyde, characterised by a roasted peanut aroma, and benzyl alcohol giving faint aromatic and volatile oil-of-almond aroma, also furfural with almond like odour and n-decanoic acid with rancid, unpleasant odour, mostly formed in the process of lipid hydrolysis and oxidation (Jiang et al., 2022). Volatile compounds in meat are affected by cooking time and temperature and different reactions during the process (like Maillard reaction) and a series of nutrient degradation (Jiang et al., 2022). There is no caraway odour found in the meat sample.

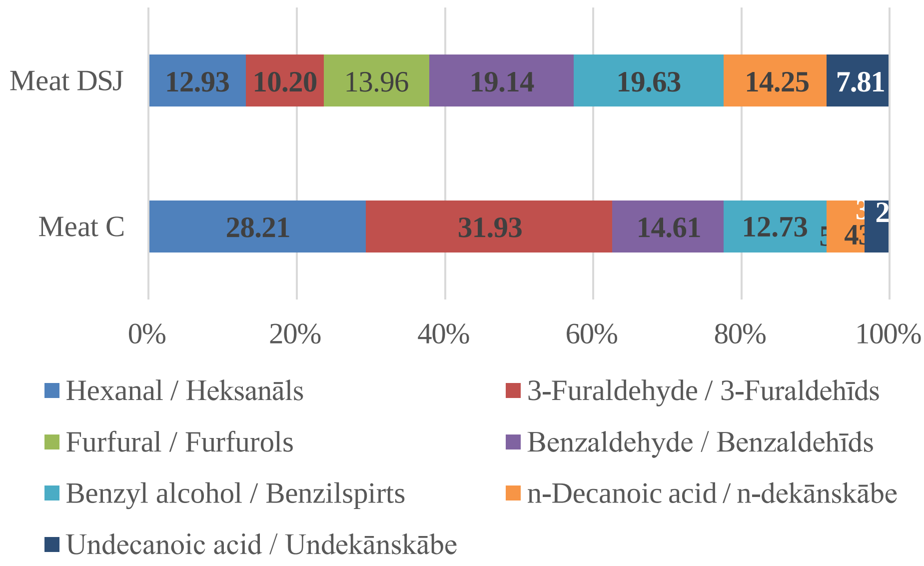

Fig. 3.23. **The percentage of volatile compound peak areas in the meat samples, % /**
3.23. att. Gaistošo savienojumu procentuālais daudzums gaļas paraugos, %

A sensory evaluation was carried out in the meat samples just like described above in the bread samples applying the Hedonic scale. Due to DSJ specific aroma and taste properties, it was useful to distinguish the effect and differences between the control and DSJ sample. In the bread samples statistics showed no significant differences between samples but for meat samples a different trend was observed, as shown in Figure 3.24.

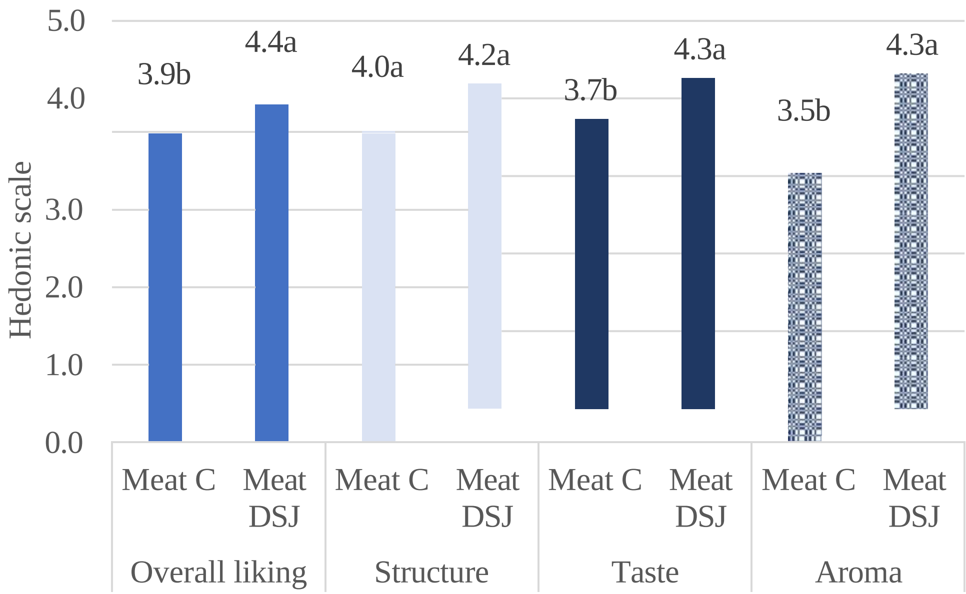

Fig. 3.24. **Hedonic evaluation of the meat samples /**
3.24. att. Maizes paraugu vērtēšana pēc hedoniskās skalas
The same letter along the values shows that the difference between two samples is not statistically significant

No significant differences were in the structure ($p<0.05$) of the samples whereas significant differences in the overall liking, taste and aroma of the samples ($p>0.05$) were determined and in all cases higher evaluation was for samples with added DSJ. It could be explained by traditional cooking and serving of meat with sauerkraut and these tastes are pairing for Latvian consumers and be acceptable and highly evaluated. Therefore, meat products could be prospective for application of DSJ in food.

Summary of Chapter 3.4. / 3.4. nodaļas kopsavilkums

Dehydrated sauerkraut juice was tested in food applications as a salt alternative, and its possible reduction in experimental salad dressings with olive oil and sour cream. Nor salt nor dehydrated sauerkraut juice dissolves in oil bringing the salty sensation to the mouthfeel in the experimental samples with olive oil. The overall liking among the samples is highest in the OO2 samples – with slightly reduced salt amount.

DSJ dissolves in sour cream and brings not only a salty sensation but also additional tastes like garlic, yogurt and mayonnaise. The overall liking among the samples is the highest in SC2, with slightly reduced salt amount. The taste compounds in the samples SC1 and SC3 were characterised as either too strong or too weak, accordingly.

Overall, experimental samples with DSJ were liked more than the control sample with salt. This leads to the conclusion that DSJ could be used in salad dressingsa as salt alternative, reducing the consumed salt amount and enriching the food with minerals and bioactive compounds.

DSJ enriches bread and meat samples with total phenol content and antiradical activity, however, high bioactive compound content does not always mean high bioaccessibility of them. The bioaccessibility of total phenol content in the bread control samples was higher and index exceeds 1, and is considered as good.

The highest peak of the volatile compounds in the Bread DSJ sample was benzaldehyde with oil-of almond odour but also caraway -like odour was identified in the Bread DSJ sample. The highest peaks in Meat DSJ sample is also benzaldehyde with a roasted peanut aroma but also n-decanoic acid with rancid, unpleasant odour.

In the sensory evaluation, all the samples – bread and meat – with DSJ were preferred or liked better than the control samples. Therefore, DSJ can be used in food applications exposing different taste nuances.

Dehidrēta skābētu kāpostu sula tika testēta pārtikas produktos kā sāls alternatīva, un tā iespējamais samazinājums eksperimentālajās salātu mērcēs ar olīveļļu un skābo krējumu. Ne sāls, ne dehidrēta skābētu kāpostu sula (DSJ) nešķīst eksperimentālajos paraugos ar eļļu, radot sāļu sajūtu mutes dobumā. Sensorajā vērtēšanā kopējā patikšana paraugos visaugstākā bija OO2 paraugiem – ar nedaudz samazinātu sāls daudzumu.

DSJ izšķīst skābajā krējumā un rada ne tikai sāļu sajūtu, bet arī papildu garšas kā ķiploku, jogurta un majonēzes. Vislielākā patika starp paraugiem ir SC2 ar nedaudz samazinātu sāls daudzumu. Garšas savienojumi paraugos SC1 un SC3 tika attiecīgi raksturoti kā pārāk spēcīgi vai pārāk vāji. Kopumā eksperimentālie paraugi ar DSJ patika vairāk nekā kontroles paraugs ar sāli. Tas liek secināt, ka DSJ varētu izmantot salātu mērcēs kā sāls alternatīvu, samazinot patērētā sāls daudzumu un bagātinot pārtiku ar minerālvielām un bioaktīviem savienojumiem.

DSJ bagātina maizes un gaļas paraugus ar kopējo fenolu saturu un antiradikālo aktivitāti, tomēr augsts bioaktīvo savienojumu saturs ne vienmēr nozīmē augstu to biopieejamību. Kopējo fenolu satura biopieejamība maizes kontroles paraugos bija augstāka un indekss pārsniedz 1, un tiek uzskatīts par labu.

Visizteiktākie gaistošie savienojumi Bread DSJ paraugā bija benzaldehīds ar mandeļu eļļas smaržu, bet tika konstatēts arī ķimenēm līdzīgs aromāts. Meat DSJ paraugā visizteiktākie *savienojumi bija benzaldehīds ar grauzdētu zemesriekstu aromātu, kā arī n-dekānskābe ar sasmakušu, nepatīkamu smaku.*

Sensorajā vērtējumā visiem paraugiem ar DSJ – maizei un gaļai – tika dota priekšroka vai patika labāk nekā kontroles paraugi. Tāpēc DSJ var izmantot pārtikas produktos, atklājot dažādas garšas nianses.

CONCLUSIONS / *SECINĀJUMI*

1. **The composition of sauerkraut juice is affected by the variety and harvest year of white cabbage used and the variation of total phenol content, antiradical activity and ascorbic acid is significant.** / *Skābētu kāpostu sulas sastāvu ietekmē izmantoto balto kāpostu šķirne un ražas gads, un TPC, antiradikālās aktivitātes un askorbīnskābes rezultātu izkliede ir nozīmīga.*

2. **Sauerkraut juice contains minerals (potassium, calcium, iron etc), sugars, salt (0.75 g 100 g^{-1}), lactic acid bacteria and is a valuable raw material. To enable its use in food applications, it is essential to reduce its moisture content.** / *Skābētu kāpostu sula satur minerālvielas (kāliju, kalciju, dzelzi u.c.), cukurus, sāli (0,75 g 100 g^{-1}), pienskābes baktērijas un ir uzskatāma kā vērtīga izejviela. Lai to varētu izmantot pārtikas nozarē, ir būtiski samazināt sulas mitruma saturu.*

3. **The evaporation technology affects the physicochemical properties of concentrated sauerkraut juice. Falling film and open kettle evaporated sauerkraut juice contains higher total phenol and ascorbic acid content, while rotary vacuum evaporated concentrated sauerkraut juice contains higher lactic acid bacteria count.** / *Ietvaices tehnoloģija ietekmē koncentrētas skābētu kāpostu sulas fizikāli ķīmiskās īpašības. Krītošās plēves un atvērta tipa katlā iztvaicētā sula satur lielāku kopējo fenolu un askorbīnskābes saturu, savukārt rotācijas vakuumā ietvaicētā sula satur lielāku pienskābes baktēriju skaitu.*

4. **Concentrated sauerkraut juice produced by falling film evaporation contain minerals, such as potassium (1358 mg 100 g^{-1}), calcium (238 mg 100 g^{-1}), iron (1137µg 100 g^{-1}), as well as vitamin C (110 mg 100 g $^{-1}$), sugars, and is a source of NaCl (6.33 g 100 g^{-1}).** / *Krītošās plēves ietvaicē koncentrēta skābētu kāpostu sula satur minerālvielas, piemēram, kāliju (1358 mg 100 g^{-1}), kalciju (238 mg 100 g^{-1}), dzelzi (1137 µg 100 g^{-1}), kā arī C vitamīnu (110 mg 100 g $^{-1}$), cukurus, un ir NaCl (6,33 g 100 g^{-1}) avots.*

5. **Dehydrated sauerkraut juice can be dried in a horizontal spray-dryer without a carrier agent while maintaining high total phenolic content, antiradical activity and lactic acid bacteria count.** / *Dehidrētu skābētu kāpostu sulu ir iespējams izkaltēt horizontālā izsmidzināšanas kaltē bez nesējvielas, saglabājot augstu uzturvērtību, kopējo fenolu daudzumu, antiradikālo aktivitāti un pienskābes baktērijas.*

6. **Starch solution (sauerkraut juice: starch solution - 50:75) is a suitable carrying agent for the production of vertically spray-dried sauerkraut juice. Dehydrated sauerkraut juice contains phenol compounds, vitamin C (98 mg 100 $^{g-}$1), minerals, such as potassium (1457 mg 100 g^{-1}), calcium (297 mg 100 g^{-1}), iron (1.5 mg 100 g^{-1}), as well as vitamin C (98 mg 100 g $^{-1}$), sugars, and is a source of NaCl (1.05 g 100 g^{-1}).** / *Cietes šķīdums (50:75) ir piemērota nesējviela dehidrētas skābētu kāpostu sulas iegūšanai vertikālajā izsmidzināšanas kaltē. Dehidrēta skābētu kāpostu sula satur fenolu savienojumus, C vitamīnu (98 mg 100 g^{-1}), minerālvielas, piemēram, kāliju (1457 mg 100 g $^{-1}$), kalciju (297 mg 100 g^{-1}), dzelzi (1,5 mg 100 g^{-1}), kā arī C vitamīnu (98 mg 100 g $^{-1}$), cukurus, un ir NaCl avots (1,05 g 100 g^{-1}).*

7. **During the RATA sensory evaluation of salad dressings, containing dehydrated sauerkraut juice (DSJ), consumers rated additional flavors such as garlic, yogurt, and mayonnaise and the samples with reduced salt-equivalent maintained an equal salty sensation.** / *Eksperimentālo salātu mērču sensorajā RATA novērtēšanā, patērētāji atzīmēja*

papildus garšas, piemēram, ķiploku, jogurta un majonēzes, un paraugi ar samazinātu sāls ekvivalentu (ar dehidrētu skābētu kāpostu sulu) saglabāja līdzvērtīgi sāļu sajūtu.

8. **The addition of dehydrated sauerkraut juice to bread samples increased their total phenol content and antiradical activity, however, did not increase the bioaccessibility of these compounds Sensory evaluation did not reveal any significant differences between tested bread samples. /** *Dehidrētas skābētu kāpostu sulas pievienošana maizes paraugiem paaugstināja to kopējo fenolu saturu un antiradikālo aktivitāti. Sensorais novērtējums neatklāja nekādas būtiskas atšķirības. Dehidrētas skābētu kāpostu sulas pievienošana nepalielināja šo savienojumu bioloģisko pieejamību.*

9. **In sensory evaluations of meat samples, the addition of both - dehydrated and concentrated sauerkraut juice resulted in higher ratings for overall liking, taste, texture, and flavour. The addition of dehydrated sauerkraut juice to the meat samples increased their antiradical activity.** / *Gaļas paraugu sensorajā vērtēšanā, pievienojot gan dehidrētu, gan koncentrētu skābo kāpostu sulu, tika iegūti augstāki vērtējumi attiecībā uz kopējo patikšanu, garšu, tekstūru un garšu. Dehidrētas skābētu kāpostu sulas pievienošana gaļas paraugiem palielināja to antiradikālo aktivitāti.*

10. **The results of the research partially confirm the hypothesis. Dehydrated and concentrated sauerkraut juices are suitable for use in food application but sensory properties are not always acceptable.** */ Pētījuma rezultāti daļēji apstiprina hipotēzi. Dehidrēta un koncentrēta skābētu kāpostu sula ir piemērota lietošanai pārtikā, taču sensorās īpašības ne vienmēr ir pieņemamas.*

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APPENDIXES / *PIELIKUMI*

Appendix 1 / *1. Pielikums*

Dehydrated and concentrated sauerkraut juice in bread applications / *Dehidrēta un koncentrēta skābētu kāpostu sula maizes izstrādājumos*

Products / *Produkti*	**Sauerkraut products additive /** *Pievienotais skābētu kāpsotu produkts*, %	**Quality evaluations** / *Kvalitātes izvērtējums*
Moulded bread with sauerkraut juice products / *Veidņu maize ar skābētu kāpostu sulas produktiem*	3% sauerkraut juice / *3% skābētu kāpostu sula*	The taste of sauerkraut juice is not perceptible. The acidity of the bread is sufficient; amount of juice could be increased. / *Skābētu kāpostu sulas garša nav jūtama. Maizes skābums pietiekams, sulas daudzumu var palielināt*
	6% sauerkraut juice / 6% skābētu kāpostu sula	The taste of sauerkraut juice is not perceptible. The acidity of the bread is sufficient; amount of juice could be increased. / *Skābētu kāpostu sulas garša nav jūtama. Maizes skābums pietiekams, sulas daudzumu var palielināt*
	0.6% dehydrated sauerkraut juice / 0.6% kāpostu sulas pulveris	Dehydrated juice easily mixes with other ingredients. Bread taste is good, taste of sauerkraut juice is not perceptible, acidity is sufficient / *Kāpostu sulas pulveris viegli sajaucās ar pārējām sausajām sastāvdaļām. Maizes garša laba, kāpostu sulas garša nav jūtama skābums pietiekams.*
	2% sauerkraut juice concentrate / 2% koncentrēta skābētu kāpsotu sula	Bread taste is good, taste of sauerkraut juice is not perceptible, acidity is sufficient */ Maizes garša laba, kāpostu sulas garša nav jūtama skābums pietiekams.*
	3% sauerkraut juice concentrate / 3% koncentrēta skābētu kāpsotu sula	Bread taste is good, taste of sauerkraut juice is not perceptible, acidity is sufficient. Not specific benefits of added products / *Maizes garša laba, kāpostu sulas garša nav jūtama skābums pietiekams. Pievienotam koncentrātam nav izteikti pozitīvākas īpašības.*

Continuation of the appendix 1. /
1. pielikuma turpinājums

Products / *Produkti*	**Sauerkraut products additive** / *Pievienotais skābētu kāpsotu produkts*, %	**Quality evaluations** / *Kvalitātes izvērtējums*
Sausmaizītes / *Crisp-bread*	1% dehydrated sauerkraut juice / *1% skābētu kāpsotu* sulas *pulveris*	The taste of dehydrated sauerkraut juice is not noticeable, could slightly increase its amount (due to nutritional value), but so that the specific aroma is not felt and there is no sour taste. / *Kāpostu pulvera garša nav jūtama. Var nedaudz palielināt tā* daudzumu *(uzturvērtību dēļ), bet tā, lai nebūtu jūtams specifiskais aromāts un nebūtu skāba garša.*
	3% concentrated sauerkraut juice / *3% koncentrēta skābētu kāpsotu sula*	A pronounced taste of concentrated sauerkraut juice is not felt, but it is not recommended to increase its amount, so that the specific aroma is not felt and there is no sour taste / *Izteikta kāpostu sulas garša nav jūtama, bet palielināt tās daudzumu nav ieteicams, lai nebūtu jūtams* specifiskais *aromāts un nebūtu skāba garša.*
	4% concentrated sauerkraut juice / *4% koncentrēta skābētu kāpsotu sula*	The taste of concentrated sauerkraut juice is slightly noticeable. The breads are also a bit too salty. Either the amount of salt or the amount of juice should be reduced / *Kāpostu sulas garša ir nedaudz jūtama. Maizītes ir arī nedaudz par sāļu. Ir jāsamazina vai nu sāls daudzums, vai sulas daudzums.*
Rye bread with concentrated sauerkraut juice / *Rudzu maize ar koncentrētu skābētu kāpostu sulu*	2% and 3% concentrated sauerkraut juice / *2% un 3% koncentrēta skābētu kāpsotu sula*	• With 2% sauerkraut, the taste of the juice is not noticeable. Bread acidity in dough 4.3, in bread 4.1, which is a little too little (optimum in dough 4.4-4.8; 4.2-4.5 in bread). / *Ar 2% skābētu kāpostu sulas, garša nav jūtama. Maizes skābums mīklā 4.3, maizē 4.1, kas ir nedaudz par maz (optimāli mīklā 4.4-4.8; 4.2-4.5 maizē).* • With 3%, the taste and smell of sauerkraut juice is slightly noticeable. Acidity in dough 4.5, in bread 4.3, which are optimal. The taste of sauerkraut juice is not pleasant. The amount of sauerkraut should be reduced to 2.5%. / *Ar 3% nedaudz jūtama kāpostu sulas garša un smarža. Maizes skābums mīklā 4.5, maizē 4.3, kas ir optimāli. Kāpostu sulas garša nav patīkama. Kāpostu sulas daudzums jāsamazina uz 2.5%.*

Appendix 2 / *2. Pielikums*

Thermally unprocessed meat products with concentrated sauerkraut juice / ***Termiski neapstrādāti gaļas produkti ar koncentrētu skābētu kāpostu sulu***

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ,** *%*	**Apperarance /** *Izskats*	**Consistency /** *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
Onion sausage / *Sīpoldesa*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / Atbilstošs	Appropriate / Atbilstošs	Appropriate / *Atbilstošs*	5.63
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / Bez *izmaiņām*	Without differences / Bez izmaiņām	Pleasantly sharp / *Patīkami asa*	5.65
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Pleasantly sharp */ Patīkami asa*	5.61
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Pleasantly sharp / *Patīkami asa*	5.55
	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / Atbilstošs	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	4.99
		0.1	Sticky casing / *Lipīgs apvalks*	Sticky, slimy / *Lipīga, gļotaina*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Not evaluated / *Netiek vērtēta*	4.96
		1.0	Sticky casing / *Lipīgs apvalks*	Sticky, slimy / *Lipīga, gļotaina*	Acidic / *Skābena*	Without differences / Bez izmaiņām	Not evaluated / *Netiek vērtēta*	4.96
		2.0	Sticky casing / *Lipīgs apvalks*	Sticky, slimy / *Lipīga, gļotaina*	Distinct acidity / *Izteikti skāba*	Dark red / *Tumši sarkana*	Not evaluated / *Netiek vērtēta*	4.95

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ,** *%*	**Apperarance /** *Izskats*	**Consistency /** *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
Sausage / *Kupāti*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	*Appropriate / Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / Atbilstošs	5.82
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	*Without differences / Bez izmaiņām*	Without differences / *Bez izmaiņām*	Slightly more salty / *Nedaudz sāļāka*	5.8
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	More salty / *Sāļāka*	5.77
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Salty, acidic taste / *Sāļa, skāba piegarša*	5.75
	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	5.74
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Salty, acidic taste / *Sāļa, skāba piegarša*	5.65
		1.0	*Without differences / Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Salty, acidic taste / *Sāļa, skāba piegarša*	5.59
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	*Without differences / Bez izmaiņām*	Without differences / *Bez izmaiņām*	Very salty, acidic poignant taste / *Sāļa, skābi sīva piegarša*	5.54

Continuation of appendix 2 / *2. Pielikuma turpinājums*

Shashliks with concentrated sauerkraut juice / *Šašliki ar koncentrētu skābētu kāpostu sulu*

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ, %**	**Apperarance /** *Izskats*	**Consistency /** *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
Grilled meat "Klasiskais" / *Šašliks "Klasiskais"*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / Atbilstošs	Appropriate / *Atbilstošs*	5.1
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	*Without differences / Bez izmaiņām*	Characteristic for sauerkraut / *Skābētiem kāpostiem raksturīga*	5.05
		0.5	Without differences / *Bez izmaiņām*	Dry, crumbling / *Sausa, drūpoša*	Acidic, vinergar / *Skābena, etiķaina*	Without differences / *Bez izmaiņām*	Intensive, characteristic for sauerkraut / *Izteikta skābētiem kāpostiem raksturīga*	5.02
		1.0	Without differences / *Bez izmaiņām*	Dry / *Sausa*	Acidic / *Skābena*	Intensive red / *Izteikti sārta*	Acidic, spicy, intensive characteristic for sauerkraut / *Skābi pikanta, izteikta skābētiem kāpostiem raksturīga*	5.05
	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	*Appropriate / Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	5.0
		0.1	Without differences / *Bez izmaiņām*	Dry / *Sausa*	Without differences / *Bez izmaiņām*	Without differences / Bez izmaiņām	Sharper, intensive, acetic / *Asāka, izteiki etiķaina*	5.08
		0.5	Without differences / *Bez izmaiņām*	Dry / *Sausa*	Intensive acidic / *Izteikti skābena*	Sārtāka / More red	Intensive characteristic for sauerkraut / *Izteikta skābētiem kāpostiem raksturīga*	5.0
		1.0	Without differences / *Bez izmaiņām*	Dry, fibrous, crumbling / *Sausa, šķiedraina, drūpoša*	Characteristic for sauerkraut / *Skābētiem kāpostiem raksturīga*	Intensive red / Izteikti sārta	Acidic, intensive characteristic for sauerkraut, unpleasant / *Skābi pikanta, izteikta skābētiem kāpostiem raksturīga, nepatīkama*	4.98

Continuation of appendix 2 / *2. Pielikuma turpinājums*

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ, %**	**Apperarance /** *Izskats*	**Consistency /** *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
Pork grilled meat in mayonnaise / *Cūkgaļas šašliks majonēzē*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	5.27
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	5.62
		0.5	Without differences / *Bez izmaiņām*	Juicy / *Sulīgāka*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Lightly acidic / *Viegli skābena*	5.39
		1.0	Without differences / *Bez izmaiņām*	Juicy / *Sulīgāka*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Acidic, spicy / *Skābi pikanta*	5.19
	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	5.15
		0.1	Without differences / *Bez izmaiņām*	Juicy /*Sulīgāka*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Spicy / *Pikantāka*	5.15
		0.5	Without differences / *Bez izmaiņām*	Juicy, tender / *Sulīgāka, mīkstāka*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	5.11
		1.0	Without differences / *Bez izmaiņām*	Loosy / *Irdena*	Characteristic to sauerkraut / *Skābētiem kāpostiem raksturīga*	Without differences / *Bez izmaiņām*	Characteristic to sauerkraut, unpleasant / *Skābētiem kāpostiem raksturīga, nepatīkama*	4.86

Continuation of appendix 2. / *2. Pielikuma turpinājums*

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ,** *%*	**Apperarance /** *Izskats*	**Consistency /** *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
Crickets / *Grillspārniņi*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	*Appropriate / Atbilstošs*	5.66
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Slightly acidic, spicy / *Nedaudz skāba, pikantāka*	5.63
		0.5	Without differences / *Bez izmaiņām*	Juicy / *Sulīgāka*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Distinct, spicy / *Izteiktāka, pikantāka*	6.01
		1.0	Without differences / *Bez izmaiņām*	Juicy / *Sulīgāka*	Distinct / *Izteiktāka*	Without differences / *Bez izmaiņām*	Distinct, spicy / *Izteiktāka, pikantāka*	5.96
	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	5.64
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Slightly acidic, spicy / *Nedaudz skāba, pikantāka*	5.63
		0.5	Without differences / *Bez izmaiņām*	Juicy / *Sulīgāka*	Distinct / *Izteiktāka*	Without differences / *Bez izmaiņām*	Distinct, spicy / *Izteiktāka, pikantāka*	5.55
	Fresh / *Svaigs*	1.0	Without differences / *Bez izmaiņām*	Juicy / *Sulīgāka*	Slightly acidic / *Nedaudz skāba*	Without differences / *Bez izmaiņām*	Acidic, slightly unpleasant aftertaste / *Skābena, nepatīkama skāba pēcgarša*	5.45

Continuation of appendix 2. */* *2. Pielikuma turpinājums*

Boiled meat products with concentrated sauerkraut juice / Vārīti gaļas produkti ar koncentrētu skābētu kāpostu sulu

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ, %**	**Apperarance /** *Izskats*	**Consistency /** *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
Boiled doctor sausage / *Vārītā Doktora desa*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	*Appropriate / Atbilstošs*	6.14
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.08
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Slightly acidic / *Viegli skāba*	6.05
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Salty with acidic taste / *Sāļa, ar skābu piegaršu*	6.03
	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.09
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.09
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Slightly acidic / *Viegli skāba*	6.03
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Izteikti skāba*	Without differences / *Bez izmaiņām*	Salty, acidic taste, bitter aftertaste / *Sāļa, ar skābu piegaršu,rūgtena pēcgarša*	5.99

Continuation of appendix 2. ***/*** *2. Pielikuma turpinājums*

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ, %**	**Apperarance /** *Izskats*	**Consistency /** *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
Small pork sausage / *Cūkgaļas cīsiņi*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.18
		0.1	Without differences / *Bez izmaiņām*	Without differences / Bez izmaiņām	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.12
		0.5	Without differences / *Bez izmaiņām*	Without differences / Bez izmaiņām	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.12
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Salty, slightly acidic taste / *Sāļa, neliela skāba piegarša*	6.08
	After storage / *Pēc uzglabāšanas*	0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Appropriate / *Atbilstošs*	6.13
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.05
		0.5	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Slightly more salty, acidic taste / *Nedaudz sāļāka, skāba piegarša*	6.03
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Slightly more salty, acidic taste *Nedaudz sāļāka, skāba piegarša*	5.7

Product / *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*
Pork sausages / *Cūkgaļas sardeles*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.14
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.12
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Slightly more salty / *Nedaudz sāļāka*	6.08
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Salty, with slightly acidic taste / *Sāļa, ar nelielu skābu pie-garšu, nepatīkama pēcgarša*	6.06
	After storage / Pēc uzglabāšanas	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.20
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Bez izm Without differences / *Bez izmaiņām aiņām*	6.13
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	More salty, weak acidic taste / *Sāļāka, vāji skāba piegarša*	6.09
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Salty, acidic taste, unpleasant aftertaste / *Sāļa, ar skābu piegaršu, nepatīkama pēcgarša*	6.03

Product / *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*	**Product /** *Produkts*
Pate with carrots and greens / *Pastēte ar burkāniem un zaļumiem*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / Atbilstošs	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.30
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Bez izm Without differences / *Bez izmaiņām aiņām*	6.26
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Slightly acidi taste / *Viegli skāba piegarša*	6.24
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Distinct salty, unpleasant aftertaste / *Izteikti sāļāka, nepatīkama pēcgarša*	6.19
	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.30
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.26
		1.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic taste / *Skābena piegarša*	6.24
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Darker / *Tumšāka*	Distinct acid with poisant aftertaste / *Izteikti skāba, ar sīvu pēcgaršu*	6.24

Smoked and dried meat products / *Kūpināti un žāvēti gaļas produkti*

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ, %**	**Apperarance** / *Izskats*	**Consistency** / *Konsistence*	**Aroma** / *Smarža*	**Colour** / *Krāsa*	**Taste** / *Garša*	**pH**
Smoked chicken with garlic / *Kūpināta vista ar ķiplokiem*	Fresh / *Svaigs*	0	*Appropriate / Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.13
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	5.95
		1.0	Without differences / *Bez izmaiņām*	Juicy, soft / *Sulīgāka, maiga*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Slightly acidic, characteristic to sauerkraut, bitter / *Nedaudz skāba, skābētiem kāpostiem raksturīga*	5.90
		2.0	Without differences / *Bez izmaiņām*	Juicy, soft / *Sulīgāka, maiga*	Acidic / *Skāba*	Without differences / *Bez izmaiņām*	Slightly acidic, characteristic to sauerkraut / *Nedaudz skāba, skābētiem kāpostiem raksturīga, nedaudz rūgta*	5.21
	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	5.8
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	5.79
		4.0	Without differences / *Bez izmaiņām*	Dry / *Sausa*	Acidic / *Skāba*	Without differences / *Bez izmaiņām*	Intensive acid, salty, bitter aftertaste / Izteikti *skāba, sāļa, ar sīvu, rūgtu pēcgaršu*	5.39

Continuation of appendix 2. */ 2. Pielikuma turpinājums*

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ, %**	**Apperarance** */ Izskats*	**Consistency** / *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
		6.0	Without differences / *Bez izmaiņām*	Intensive dry / *Izteikti sausa*	Acidic / *Skāba*	Without differences / Bez izmaiņām *Bez izmaiņām*	Intensive acid, salty, bitter aftertaste / *Izteikti skāba, sāļa, ar sīvu pēcgaršu*	5.17
Smoked pork ham / *Kūpināts cūkgaļas šķiņķis*	Svaigs / *Fresh*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.4
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.25
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	*Without differences / Bez izmaiņām*	Slightly salty, astringent aftertaste / *Nedaudz sāļāka, sīva pēcgarša*	6.02
		5.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Intensive salty, astringent aftertaste / *Izteikti sāļa, sīva pēcgarša*	6.08

Continuation of appendix 2. */ 2. Pielikuma turpinājums*

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ, %**	**Apperarance** / *Izskats*	**Consistency** / *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
Smoked pork ham / *Kūpināts cūkgaļas šķiņķis*	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.17
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.09
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Salty, astringent aftertaste / *Sāļa, sīva pēcgarša*	5.67
		5.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Intensive salty, long astringent aftertaste / *Izteikti sāļa, ilgstoši sīva pēcgarša*	5.35
		7.0	Without differences / *Bez izmaiņām*	Dense, consistent / *Blīva, sīksta*	Acidic with rancid notes / *Skāba, ar sasmakumu*	Uneven staining of muscle tissue / *Nevienmērīgs muskuļaudu krāsojums*	Intensive salty, acid, astringent, bitter aftertaste / *Izteikti sāļa, skāba, ilgstoši sīva, rūgta pēcgarša*	5.49

Continuation of appendix 2. */ 2. Pielikuma turpinājums*

Product / *Produkts*	**Samples /** *Paraugi*	**CSJ, %**	**Apperarance /** *Izskats*	**Consistency /** *Konsistence*	**Aroma /** *Smarža*	**Colour /** *Krāsa*	**Taste /** *Garša*	**pH**
Semi-dried sausage "Krakova" / *Puszāvētā desa "Krakovas"*	Fresh / *Svaigs*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.4
		0.1	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	6.35
		2.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Acidic / *Skābena*	Without differences / *Bez izmaiņām*	Acidic / *Skābena* Skābena	6.31
		4.0	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Sharp, characteristic of sauerkraut, rancid /*Asa, raksturīga skābētiem kāpostiem. Ar sasmakumu*	Without differences / *Bez izmaiņām*	Acid, astringent aftertaste / *Skāba, ar sīvu pēcgaršu*	6.28
	After storage / *Pēc uzglabāšanas*	0	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	*Appropriate / Atbilstošs*	Appropriate / *Atbilstošs*	Appropriate / *Atbilstošs*	6.34
		0.1	Mold on casing / *Uz apvalka pelējums*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Without differences / *Bez izmaiņām*	Not evaluated / *Netiek vērtēta*	6.32
		2.0	Mold on casing / *Uz apvalka pelējums*	Without differences / *Bez izmaiņām*	Intensive cinnamon aroma / *Izteikts kanēļa aromāts*	Without differences / *Bez izmaiņām*	Not evaluated / *Netiek vērtēta*	6.25
		4.0	High amount of mold on casing / *Uz apvalka pelējums lielā daudzumā*	Without differences / *Bez izmaiņām*	Intensive cinnamon aroma, acidic / *Izteikts kanēļa aromāts, skābena*	Without differences / *Bez izmaiņām*	Not evaluated / *Netiek vērtēta*	6.20