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AACC	American Association of Cereal Chemists
AAS	Atomic Absorption Spectroscopy
AES	Atomic Emission Spectroscopy
AGES	Agentur für Gesundheits- und Ernährungssicherheit
ASU	Amtliche Sammlung von Untersuchungsverfahren
cv	Coefficient of variation
BU	Brabender Unit
CVD	Carviovascular Disease
DASH	Dietary Approaches to Stop Hypertension
DGE	Deutsche Gesellschaft für Ernährung
EFSA	European Food Safety Authority
ESAN	European Salt Action Network
HMW	High molecular weight
ICC	International Association for Cereal Science and Technology
ICP-MS	Inductively Coupled Plasma
ICRG	Intersalt Cooperative Research Group
ISE	Ion Selective Electrode
LMBG	Lebensmittel - und Bedarfsgegenständegesetz
LMW	Low Molecular Weight
R	Resistance to extension
R_{max}	Maximum resistance to extension
SBP	Systolic Blood Pressure
sd	Standard deviation
TOHP	Trials of Hypertension Prevention
VfG	Versuchsanstalt für Getreideverarbeitung
WASH	World Salt Awareness Week
WHO	World Health Organisation
YOM	Year Of Manufacture

1 INTRODUCTION

In ancient times, salt was a very rare and precious good which was used in an economical way. Nowadays, it is abundant and no one has to care about sparing any longer. Salt (i.e. sodium chloride) intake has been increasing for decades, as processed food with high levels of sodium is getting more and more common in the human diet.

Table salt is highly appreciated as a flavouring compound and it is part of worldwide everyday nutrition. For a long time there was no regulation on salt consumption. But for a few years, publications of several investigations on possible negative effects of high salt consumption on human health – like a higher prevalence of hypertension, CVD and other related diseases – have been causing changes in thought. The reason for these lifestyle diseases was found to be very often a high daily intake of sodium, which is just one part of NaCl. Sodium can also be found in other food components and beverages, but the largest daily intake by far derives from salt.

WHO now suggests a daily salt intake of less than 5 g and the D - A - CH reference value is settled at less than 6 g per day. Stated goal of politics is to reach these suggestions in order to promote health and decrease health insurance expenditures with the help of preventive measures.

The first step concerning the salt adjustment process is the Health Claims Regulation (Art. 4) (EG) Nr. 1924/2006, published in the official journal of the European Union, which states parameters on nutritional profiles and health - and nutrition claims, inter alia about the amounts of sugar, saturated fatty acids and also salt. Therefore it will be no longer possible to promote healthy food products as being “healthy”, when they contain too much salt. For example, if a producer wants to promote his bread as “rich in dietary fibre” but the bread contains too much salt, then this advertisement has to be banned.

In Austria, the compliance with this regulation will soon be monitored by the AGES. Other European countries like Finland, Switzerland and Great Britain have already set a good example and show that it is not impossible to control food manufacturers and individual salt consumption.

Although bread does not contain as much salt compared to processed meat or cheese, it is still essential to control its salt level because of its importance as an every-day staple food and thus for its higher consumption rate.

But a salt reduction in terms of bread and small baked goods could get difficult, as these products require certain amounts of salt for technological reasons, below which proper processing and a satisfying consistency of the end product can no longer be guaranteed. Another problem, seen by many bakers is customer acceptance of salt - reduced products.

The Austrian bakers guild is now trying to recruit bakers to join their voluntary salt reduction program. Their aim is to generally reduce percentage of salt in bread and small baked goods in Austria down to a level of 1,7 % mas on flour basis.

2 SALT AND HUMAN METABOLISM

2.1 BASICS ABOUT SODIUM AND ITS BODY FUNCTIONS

Table salt, often simply referred to as "salt", is a mineral composed almost entirely of sodium (Na^+ as cationic part, 40 % mas) and chloride (Cl^- as anionic part, 60 % mas) (BELITZ et al., 2001). In human nutrition it is used as a very important seasoning, flavour enhancer and, in large quantities, as food preservative. Concerning the salt reduction dilemma, however, the crucial factor of salt is sodium exclusively; therefore it will be discussed in detail.

The human body needs sodium for its functions – nevertheless within certain doses. Sodium, the major cation in human extracellular fluid, plays an important role in regulating extracellular fluid volume. It is also jointly responsible for the maintenance of membrane potentials and functions as well as for cellular osmoregulation. Furthermore, sodium is essential for muscle contraction and sensitivity, enzymatic activation and for monosaccharide and amino acid transport (ELMADFA and LEITZMANN, 2004).

Sodium is excreted via urine at about 95 %. 4 % of sodium is eliminated via faeces and usually about 1 % is excreted via sweat, dependant on physical activity and climate conditions (LANG and LANG, 2007). Under normal circumstances, urinary sodium excretion in healthy people is in balance with the intake (ROSE, 1987). Concerning physiological processes, the minimal daily requirement of sodium is estimated at about 550 mg per day (1,4 g salt) (DGE, 2000).

Nevertheless, sodium should be seen as a mixed blessing. Possible disadvantages of sodium have been discovered and discussed in many studies for a long time and will be treated in the following chapters.

2.1.1 SODIUM AND HYPERTENSION

Hypertension is defined as high blood pressure with more than 140 mmHg systolic and more than 90 mmHg diastolic (THEWS et al., 1999). According to KEARNEY et al. (2005) about 972 million adults worldwide (26,4 %) suffered from high blood pressure in the year 2000. The prevalence of hypertension in 2025 is estimated at 1,56 billion people, which means a rise of about 60 %. In 2006/07 20 % of adult Austrian population stated, that they have had high blood pressure before (ANONYM, 2008).

Blood pressure can be influenced by age, body mass index and physical activity level as well as by dietary sodium and potassium intake (HE and MACGREGOR, 2010). Sodium was discovered to cause an increase in blood pressure, whereas potassium has a contrary effect.

It was found that reactions due to high amounts of salt differ among individuals. Usually, a varying salt consumption has only little effect on blood pressure. But 15 - 25 % of worldwide normotensive and 30 - 40 % of hypertensive individuals are “salt-sensitive” (SUTER, 2003). Their reaction to high salt intake is more severe compared with salt resistant individuals. This sensitivity often occurs with people with hypertension, diabetes, chronic heart disease, metabolic syndrome, in African-Americans, genetically predisposed individuals and in people older than 40 years of age. Salt sensitivity can be measured in individuals by a reduction of mean blood pressure at more than 10 mmHg when under salt restriction (SCHAUDER and OLLENSCHLÄGER 2006; SANDERS, 2009).

The World Health Organisation (WHO) calls hypertension the “burden of disease”. This may be true, as untreated hypertension gets associated with other diseases like diabetes, stroke, kidney disease or cardiovascular disease (CVD). About 60 % of worldwide stroke and about 50 % of coronary heart disease can be related to elevated blood pressure (HE and MACGREGOR, 2010).

Many experimental and epidemiological studies have been made so far in order to find a correlation between salt and hypertension.

The “Intersalt” study by ICRG (INTERSALT Cooperative Research Group) in 1988 was one of the first and most famous studies on salt and hypertension that was able to create a link between salt intake and blood pressure. The study was based on standardized worldwide epidemiologic investigations in 52 communities within 32 countries. 24 h urinary sodium excretion and blood pressure of 10.079 participants aged 20 to 59 years were collected and compared between all laboratories. Data were collected from 1985 until 1987. Four communities had a very low salt intake with less than 3 g per day. They all lived in non - industrialized regions. The other communities had salt intakes ranging from 6 g to 12 g per day, average daily intake was 9,9 g. The result of the study was a significant positive correlation between systolic blood pressure and 24 h sodium excretion. The authors estimated a decrease in blood pressure by 3 - 6 mmHg systolic and 0 - 3 mmHg diastolic when sodium excretion was decreased by 100 mmol per day. This would cut down the incidence of cardiovascular death by 7 - 14 %. A significant relationship between age, blood pressure and salt could be found as well. In 1996, after some critics, the ICRG re-analysed their data in another statistical way and found a correlation between high blood pressure and salt intake that was even higher than before (ELLIOTT et al., 1996). Several following meta-analyses were able to confirm a blood pressure decreasing impact of salt reduction (CUTLER et al., 1997; HE and MACGREGOR, 2002).

PIMENTA et al. (2009) discovered that clinical treatment of resistant hypertension gets highly influenced by salt intake and salt should therefore be considered in the hypertension therapy process. As an explanation, the definition for resistant hypertension is a non-responding to at least three medications.

The reasons why sodium chloride causes a raise in blood pressure are still not totally clear. One explanation could be a restricted ability to excrete sodium in the kidney and therefore too much sodium circulating in the body (DAHL et al., 1974). The rise in sodium was suggested to come along with a rise in extracellular fluid. Somehow, the human body tries to counterbalance this effect by finally elevating blood pressure to help the kidney in its struggle with such high amounts of fluid to get them out of the body (HE and MACGREGOR, 2010). WIRTH et al. (2008) tried to find a mechanism for this phenomenon in an animal-study. They detected certain transmitters that showed a muscle contracting effect in blood vessels via g-protein-coupled receptors when sodium was given to mice.

On the other hand, a small change in sodium plasma as a reason of salt intake was estimated to have major effects on blood pressure (HE et al., 2005), whereas a subsequent study was not able to find a connection between serum sodium and blood pressure (LAGO et al., 2008).

Tab. 1 (BIBBINS-DOMINGO et al., 2010) shows a summary of several study outcomes on salt reduction and its decreasing effects on systolic blood pressure among U.S.-Americans. The table also points out the different and more severe response of African- Americans to salt, probably due to a higher salt sensitivity.

Tab. 1: Estimated Changes in SBP* (mmHg) associated with reductions in dietary salt (adapted from BIBBINS-DOMINGO et al., 2010)

Group	Salt reduction 1 g/day		Salt reduction 3 g/day	
	Low Estimate of SBP Decrease	High Estimate of SBP Decrease	Low estimate of SBP Decrease	High Estimate of SBP Decrease
Entire U.S. population				
Persons with hypertension	1,20	1,87	3,60	5,61
Persons ⩾ 65 yr old	1,20	1,87	3,60	5,61
All others	0,60	1,17	1,80	3,51
Black subpopulation				
Persons with hypertension	1,80	3,03	5,40	9,10
Persons ⩾ 65 yr old	1,20	1,87	3,60	5,61
all others	1,20	1,87	3,60	5,61

*Systolic Blood Pressure

2.1.2 SODIUM AND CARDIOVASCULAR DISEASE

Cardiovascular disease (CVD) is the preamble for a class of diseases that involve heart and/or blood vessels. To presume, the first common cause of these diseases is atherosclerosis. Some examples are stroke, coronary heart disease, myocardial infarction or rheumatic heart disease. Major risk factors for CVD are elevated blood pressure, tobacco smoke, alcohol, overweight, high blood cholesterol, physical inactivity, age, stress, diabetes mellitus and heredity. Elevated blood pressure causes a morbid pressure on the vascular system. Therefore, the heart is forced to increase its pump pressure, i.e. it becomes more susceptible to CVD (HARDMAN and STENSEL, 2009). In 2003, the WHO stated the influence of sodium on the risk of cardiovascular disease being ”convincing”.

A 10 to 15 years long-term follow-up of two randomized dietary intervention trials (TOHP I, II) on salt reduction and its effect on the risk of cardiovascular disease outcomes showed that people with pre - hypertension (120 - 139 mmHg systolic and 80 – 89 mmHg) could get a 25 – 30 % lower risk of cardiovascular disease when under salt restriction. The results were significant for both normal weight and overweight people (COOK et al., 2007).

HE et al. (1999) on the other hand could not state a significant correlation between salt intake and cardiovascular risk in normal weight persons, while a high salt intake in obese people gave obvious results concerning mortality.

BIBBINS-DOMINGO et al. (2010) pre-calculated a reduction in annual new cases of coronary heart disease by 60.000 – 120.000 in U.S.-Americans if a reduction of 3 g salt per day would be achieved. The number of strokes would decrease by 32.000 - 66.000 new cases; women were found to respond more likely to a salt reduction. Myocardial infarction was estimated to decrease from 54.000 to 99.000 new cases a year. The study also tried to assess possible savings in health care costs by salt reduction and they concluded that every year $ 10 - 24 billion dollar could be put aside in the U.S. if people would reduce their salt intake. Their conclusion was that a reduction in salt would cost less money in comparison to annual expenditures on anti-hypertensive medication.

The worldwide death rate due to stroke would diminish by about 250.000 (23 %) and about 3 million (17 %) people less would die because of cardiovascular disease at a reduction from 10 g to 5 g salt per day. These were the results of a meta-analysis of 13 studies with more than 170.000 test persons (STRAZZULLO et al., 2009).

2.1.3 SODIUM AND OTHER DISEASES

Sodium was found to cause organ damages independent from its effect on blood pressure. One aspect is the conclusive evidence of recorded increase in calcium excretion at high sodium levels. As sodium is able to augment the volume of extracellular fluid, the glomerular filtration rate therefore also increases and more calcium can be washed out. In addition, sodium was found to compete with calcium for reabsorption in the renal tubule. Thus, not enough calcium is left to get installed in the skeleton. A rise in the risk of osteoporosis is estimated to be the result (MASSEY and WHITING, 1996; HEANEY, 2006). LIN et al. (2003) confirmed these findings in their study and in addition they found out that an increase in salt intake caused a more severe urinary calcium loss in hypertensive than in normotensive test persons. They suggested that the risk of sodium-enhanced osteoporosis is higher in hypertensive individuals. But long-term effects are still not well investigated.

During three months of randomized controlled trial NOUVENNE et al. (2010) found out that a reduction in dietary salt intake is able to reduce hypercalciuria and the risk of related crystallization of calcium oxalate. Hypercalciuria was estimated to cause a higher risk of kidney stone formation as well, as calcium is found in most urinary stones (CAPPUCCIO et al, 2000).

Furthermore, a high salt intake was already estimated having influence on the severity of asthma (MICKLEBOROUGH et al, 2005; CORBO et al., 2008), although another investigation could not find a connection (POGSON et al., 2008).

Another aspect is the fact that people with a higher daily salt consumption are eager to drink more. Unhappily, many people resort to soft drinks to quench their thirst which may lead to a higher prevalence of obesity (HE et al., 2008)

2.2 STATUS QUO: FACTS ABOUT SALT CONSUMPTION AND RECOMMENDATIONS

The average Austrian salt intake in 2008 was 9 g for male and 8 g for female adults (ELMADFA et al., 2009). According to WHO/FAO (2003), the intake goal should be 5 g or less per day. The D - A - CH reference value (D - A - CH, 2000) averages out at less than 6 g table salt or less than 2,3 g sodium per day. 6 g is the value which is calculated within Austria, too.

As said by MATTES and DONNELLY (1991) most salt amounts in daily human nutrition (about 75 %) derive from processed food. Only 15 % of the daily intake is due to adding more salt to a dish at the table. Natural sodium from food and especially from drinking water contributes 10 % of daily intake.

The average daily bread consumption in Austria adds up to about 120 g (ELMADFA et al., 2009) and mostly consists out of white and grain mixed bread. Concerning the DGE (Deutsche Gesellschaft für Ernährung) this is not enough. 50 % of energy intake should be gained from carbohydrates. They recommend a bread consumption of about 200 - 300 g per day which is equal to about four to six slices of bread (ANONYM, 2004). According to them, more importance should be given to wholemeal products.

Calculated with 120 g bread and an average current salt content (2 % mas on flour basis or 1,0 – 1,4 % mas on bread basis), about 1,7 g salt (or 0,68 g sodium) may derive from bread per day. This would mean that if bread consumption would increase to 240 g per day, which is a goal of the Austrian Food Ministry, about 3,4 g salt would derive from bread. This is more than half of the recommended daily salt intake.

A U.S.-American model study showed, that a salt reduction of 3 g per day could save the life of about 44.000 – 92.000 U.S.-Americans (BIBBINS-DOMINGO et al., 2010). This study was based on calculations using the “Coronary Heart Disease

Policy Model" which is a computer simulation on the incidence and prevalence of coronary heart diseases in U.S.-Americans aged 35 to 84 years or older. In addition, mortality and costs of coronary heart disease can be suggested with this programme as well.

Nevertheless, in the whole discussion about salt reduction, it is crucial not to forget about other factors which can control blood pressure, like a balanced diet for example. SACKS et al. (2001) wanted to show the influence of a sodium-reduced diet in connection with healthy food on blood pressure. In their study, they used the "Dietary Approaches to stop Hypertension"-diet (DASH-diet) which is rich in vegetables and fruits but low in fat. Furthermore, this diet includes many natural sources for potassium and calcium. As a result, the DASH-diet contributed to a decrease in blood pressure, both in normotensive and hypertensive test persons and a salt restriction showed an additional effect. Results of the "Trials of Hypertension Prevention Follow-Up"-study (TOHP I, II) also showed that a reduction in salt enhances measures for weight loss and weight control in order to decrease blood pressure (THE TRIALS OF HYPERTENSION PREVENTION COLLABORATIVE RESEARCH GROUP 1991; STEVENS et al., 2001).

Nowadays, 32 national organisations around the world (most of them in Europe) address themselves to salt reduction campaigns with different maximum salt intake recommendations ranging from 5 g to 8 g per day (WEBSTER et al., 2011).

In 2007, the WHO published a report with recommendations for their member states and stakeholders on how to achieve a decrease in salt intake and therefore a decrease in CVDs. Another campaign is the non-governmental organisation "World Action on Salt and Health" (WASH) with the aim to sensitize people in dealing with salt and salted processed foods. Every year they organize an awareness week under a different motto. In Europe, the "European Salt Action Network" (ESAN, founded in 2007) tries to implement WHO recommendations on how to reduce salt intake by corresponding with the industry in order to develop technological strategies. In addition, their mission is to build up a monitoring system and to make people aware of the problem. In 2008, the EU drew up the "EU Common Framework on Salt Reduction" with about the same goals as ESAN. Last but not least, several nationwide programmes dedicated themselves to this purpose, e.g. campaigns in Switzerland, Finland, France or Great Britain.

Altogether, a cooperation of government, non-governmental organisations and food industry seems to be the most effective way to achieve changes in both consumer awareness and mobilising food industry. Maybe a traffic light system or another special warning in the front of the food pack could be useful as well to influence consumer's decision. (WEBSTER et al., 2011).

Nevertheless, a 24 h urinary sodium excretion survey on changes in salt consumption within the Scottish population showed that although Scottish food industry has already reduced salt addition to their products since 2006, people still consume the same amounts of salt (i.e. about 9 g salt per day) as before the start of the nationwide salt reduction campaign (SCOTTISH CENTRE FOR SOCIAL RESEARCH, 2011).

Concerning the technological point of view for bread and small baked goods, a salt reduction down to a level of 1,5 % mas on flour basis would be technologically feasible but this might also be the lower limit (MAR, 2010). A voluntary restriction goal for the future should be a salt level of about 1,7 % mas on flour basis. Due to testimony of the Federal Ministry of Health, this goal should be reached until 2015. Nevertheless, salt reduction is not required and is based on voluntariness.

3 TECHNOLOGICAL INFLUENCES OF SALT IN DOUGH AND BREAD

The technological effects of sodium chloride on dough components and especially on elements based in flour are manifold. In order to understand them it is at first important to have a look on the special properties of flour elements like gluten and starch and furthermore on other baking agents like yeast and sourdough: definitions, the role of every ingredient in bread making and possible influences of salt are discussed below.

3.1 WHEAT GLUTEN

According to Osborne, wheat proteins can be divided into four fractions: albumins, globulins, glutelins and prolamins. Albumins and globulins play a minor role in dough rheology; they are in particular found in the germ and in the aleurone layer and account for up to 20 % mas of the wheat protein. Gluten is one fraction of globular proteins in cereal grain endosperm. It is a storage protein and the main resource (80 % mas) for proteins in the grain and can be separated into two subfractions: prolamins and glutelins. Other components of gluten are lipids (8 % mas) and carbohydrates (2 % mas) (BELITZ et al., 2001). Gluten are found in wheat, spelt, green spelt, rye, oats and barley. Wheat gluten is rich in glutamine (35 % mas) and proline (14 % mas), which means that half the protein consists of these two amino acids. It is poor in amino acids with charged side chains, like lysine. Prolamins and glutelins from wheat gluten have special names; they are called gliadin and glutenin and can be seen as crucial factors for a viscoelastic and cohesive dough, which is formed by water and wheat flour under influence of oxygen when being kneaded. They are also responsible for gas retention during fermentation by yeast as well as for dough fixing throughout the baking process. The dough forming properties of wheat flour are due to the unique physicochemical ability of gluten proteins to build up three-dimensional structures (HOSENEY, 1994).

Gliadin, with a molecular weight of about 40.000 Dalton, is a single chain monomer and gets sticky under hydration. It can be separated into α-, β-, γ- and ω-gliadins. Wheat dough gets its viscosity with the help of gliadin. The prolamin was described as an anti-blocking agent for the multi-chained glutenin (BELITZ et al., 2001).

Glutenin is a polymer which can be divided into high molecular weight (HMW) and low molecular weight (LMW) subunits with molecular weights from 40.000 to 1.000.000 Dalton. It is rubbery, tough and elastic, thus it is responsible for the dough’s property of cohesiveness and resistance to extension (SEIBEL, 2005; GRAVELAND et al., 1982). According to PAYNE et al. (1979) HMW glutenins were found to be key factors concerning dough elasticity.

3.1.1 THE ROLE OF WHEAT GLUTEN IN BREAD MAKING

There is agreement on the fact that gluten is unique in its special features to form viscoelastic dough. It’s very easy to see the importance of gluten when it is being removed and only starch is mixed with water. As a result, no dough would be formed (SCHÜNEMANN and TREU, 1993).

Gluten proteins were found to get hydrated and build up a backbone in between the starch grains by disaggregation and reaggregation mechanisms when being mixed with water. Gluten is able to bind about double the amount of water of its own weight. Starch granules get embedded in this gluten network (KINSELLA and WHITEHEAD, 1989). The gluten network is based on several intra- and intermolecular interactions, which can be divided into covalent and non-covalent bindings.

Covalent disulphide (- S – S -) bonds between cysteine residues were stated to be essential factors for gluten structure, even though the sulphur containing amino acid cysteine rarely occurs within gluten protein (up to 2,8 mol - % in wheat variety Rektor according to BELITZ et al., 2001). Researchers isolated cystine peptides from either HMW, LMW glutenin and gliadin fractions and they detected the way disulphide bonds are made. Because of their monomeric character gliadins can only form intra-molecular disulphide bonds. ω-gliadins do not play a major role regarding protein interactions; due to their lack of sulphur-containing amino acids, they cannot form disulphide-bonds, whereas α-, β- and γ-gliadins are able to protect weaker non-covalent bindings with their intrachain disulphide bonds, that do not change during baking procedure (WRIGLEY et al., 1998). Glutenins, which are polymer aggregates, form intermolecular disulphide bonds between LMW-LMW, HMW-HMW and LMW-HMW subunits (KÖHLER et al. 1993; SHEWRY and TATHAM 1997).

Non-covalent hydrogen bonds are formed via amides. Because of the high prevalence of amino acids to occur as their amides in gluten network, (HOSENEY, 1994) electrostatic hydrogen bindings seem to be very frequent, but they are not very strong and must be stabilized via covalent bonds (WRIGLEY et al., 1998). TKACHUK and HLYNKA (1968) tried to show the importance of hydrogen bonds by giving D_2O (deuterium) to the flour, which is known to form stronger hydrogen bridges than H_2O. Via several experiments, including the extensograph and the farinograph method they demonstrated that dough containing D_2O was much stronger and tougher than dough containing H_2O.

MCDONALD and GILLES (1967) found 35 % of gluten amino acids having hydrophobic side chains. Thus, cereal chemists suggested hydrophobic interactions being necessary for stabilizing gluten films as well. Gluten is insoluble in water due to the dominance of amino-acids with hydrophobic side chains. They were found to simplify dough development because of their reversible attitudes and they get stronger with rising temperature (WRIGLEY et al., 1998).

Ionic residues are very low in gluten. At normal pH value and with no salt added, practically no ions can be found in dough because of the low amount of amino acids with basic or acid side chains (BELITZ et al., 2001). But ionic interactions still seem to play a role in dough structure. This could be demonstrated by KIEFFER et al. (1983) after the addition of bipolar amino carboxylic acids like glycine or dicarboxylic acids which caused strengthening effects on rheological behaviour in dough. Furthermore, a notable argument seems to be the dough strengthening effect of NaCl as mentioned by WIESER (2007).

Finally, weak Van der Waals forces between neighbouring atoms were also stated to influence gluten interactions (SALVADOR et al., 2006).

By mixing the flour with water, gluten particles are being distributed throughout the dough, until a stable backbone is built up. The mixing time needed to reach the highest dough consistency is very important to make bread with maximum dough volume, as dough and more concrete gluten is susceptible to over-mixing or under-mixing. During the mixing process the glutenin molecules stretch and form sheets via breakage and reformation of disulphide bridges and hydrogen bonds (CAUVAIN and YOUNG, 2007). This film of sheets was found to break and reform networks when being over-mixed (AMEND and BELITZ, 1990). Mixing process was found to be responsible for getting starch granules embedded within the gluten matrix, too (LÉTANG et al., 1999). It is still not clear, in which way gluten interact with starch, but studies have shown rheological differences if various kinds of starch were added to the dough (PETROFSKY and HOSENEY, 1995).

One of the major roles of gluten in bread making is to keep gas within the dough. Therefore it is partially responsible for the loaf volume. During the baking process, temperatures above 60 °C induce gluten to denature and release water. Wheat starch can gelatinize in presence of water at temperatures ranging from 70 °C to 90 °C only and therefore it is now able to do so due to the water distributed by denatured gluten (MAR et al., 2007). The exact procedures of gluten transformation during the baking process still remain unclear. Together with starch, gluten forms the cut resistant, elastic crumb and is responsible for the shape of the final product.

3.1.2 WHEAT GLUTEN AND SALT

Wheat gluten in dough was found to be affected by neutral salts in several studies (HLYNKA, 1962; DANNO and HOSENEY, 1982; KIEFFER et al., 1983; HE et al., 1992). Scientists generally agree on the fact that sodium chloride is able to tighten up dough and strengthen gluten structure. (DANNO and HOSENEY, 1982; BELITZ et al., 2001; BUTOW et al., 2002). Its effect can be described as a neutralization of charged amino acid side chains and therefore allowing stronger bonding in gluten. At pH 7, gluten proteins show a slightly positive net charge (KIEFFER et al., 1983). Some amino acids have positive side chains which usually repulse one another, resulting in a weak connection within gluten. But if negative ions from NaCl are added, it comes to a neutralization of the charges; thus, gluten proteins have the chance to close ranks. These interactions were stated to be important for the stabilisation of gluten aggregates (BELITZ et al., 2001).

In general, bakers agree on the fact that salt-reduced dough is stickier and more difficult to handle. The final bread loaf has got changed crumb elasticity and is not enough relaxed (SPEIRS et al., 2009; MAR, 2010).

LYNCH et al. (2009) tried to show a correlation between salt content and extensibility/extension. In this experiment, dough samples with different salt levels (0 % mas; 0,3 % mas; 0,6 % mas and 1,2 % mas on dough basis) were prepared. Dough samples did not contain any yeast. Mixing conditions were standardized. The water amount added to the flour was the same for every dough sample, in order to avoid possible differences in rheological behaviour concerning changed water absorption (FARAHNAKY and HILL, 1997; LÉTANG et al., 1999). Measurements of dough extension and extensibility were taken using an extensograph and a Kieffer/SMS cell texture analyser. The results showed no significant differences in resistance to extension for dough samples with 0,3 % mas to 1,2 % mas of total salinity. Nevertheless, there was a significant difference between doughs having 1,2 % mas and 0 % mas salt in extensogram measurement. Dough containing no salt at all had 21 % less extension and 26 % less extensibility. According to this study, even a very small amount of salt (in this case 0,3 % mas on dough basis) was found to be able to enhance dough properties.

According to an experiment using a 10 - g mixograph, it was shown that salt increases dough strength, but it can also have an adverse effect above certain quantities. Six salt levels were investigated (0 % mas; 0,5 % mas; 1 % mas; 2 % mas; 5 % mas and 10 % mas on flour basis). At salt levels ranging from 0,5 – 5 % mas an increase in dough strength could be observed. With 10 % mas salt, dough strength got even worse than the control dough with no salt (DANNO and HOSENEY, 1982).

Inter alia, BUTOW et al. (2002) wanted to find a correlation between certain wheat cultivars and their sensitivity to various salts by measuring extensibility and resistance to extension on the extensograph. The protein content of the individual cultivars was also considered. As a result, they could confirm findings of other researchers about the dough strengthening effect of salt. Mixing times in mixograph, when salt was added, were also found to get prolonged. Nevertheless, the effect of salts on making weak wheat gluten dough even less extensible than dough with strong gluten (BENNETT and EWART, 1965) could not be confirmed. Extensibility of two very strong cultivars even deteriorated in presence of salt. Butow et al. stated that this may also be due to “reproducibility problems inherent in the extensogram methodology”.

Investigations by HLYNKA (1962) showed a decrease in dough consistency when salt was added at constant farinograph water absorption rate. The more salt was added, the less dough consistency could be observed. On the other hand, salt was found to reduce water absorption at constant consistency (in general 500 BU, according to ICC- Standard No. 115/1) which may be due to the anti- swelling effect of salt in gluten (SCHÜNEMANN and TREU, 1993). GALAL et al. (1978) once tried to explain this effect by their presumption that salt somehow occupies the connection options for water on gluten proteins and therefore decreases water absorption rate while more free water is available. This means that in presence of salt gluten are being restricted in their ability to swell and therefore less water gets absorbed by the dough.

On the other hand, HLYNKA (1962) found out that mixing time for proper dough development gets prolonged by salt, which means that more energy is required to let dough reach its development peak. At constant farinograph consistency and therefore adapted absorption rate, each 1 % mas salt caused an increase in development time of about half a minute. Hence, in relation to 2 % mas salt, which is the common amount of salt added to 100 g flour, development time may take 1 min longer. Comparable observations were made by LINKO et al. (1984).

In practice, some bakers take advantage of this knowledge by adding salt at later stages when mixing the other dough ingredients. This process is called “delayed salt method” and accelerates dough development. In addition, it also allows full hydration and development of gluten proteins before water-binding salt is added (CAUVAIN and YOUNG, 2007). It is the method of choice concerning the production of French baguettes (FREUND, 2003).

DANNO and HOSENEY (1982) found out that NaCl has a reversing effect on over-mixing, but they had incomplete justification for this phenomenon. The same effect was detected by LINKO et al. (1984), but only at over-mixed rye dough when 5 % mas salt was added. However, this phenomenon could not be observed with over-mixed wheat dough.

It has to be considered though, that not only salt can influence dough and gluten characteristics. As a matter of fact, gluten quality, temperature, mixing time/speed and pH can be regarded as crucial parameters and should be kept in mind as well (HLYNKA 1962; LARSSON, 2002).

Furthermore, recent investigations have shown that it is not so much gluten – the major part of wheat protein – that bind sodium, but albumins. In addition, it was found that only 0,01 % mas of sodium from salt is bound by wheat protein – an amount which might be negligible (HEIDOLPH et al., 2011).

3.2 WHEAT STARCH

Starch is the most important carbohydrate in wheat kernels and acts as energy storage for the plant. It is located in the endosperm and accounts for about 60 – 75 % mas of wheat kernel weight. A wheat starch granule has a characteristic lenticular and round shape with a size ranging from 20 µm to 35 µm. Starch can be divided into two classes (A and B) depending on the size and form of the granules, with A starch granules being the bigger ones. Starch granules are semi-crystalline and built up in layers. The chemical main constituent of starch is α-D-glucose. But one can also find lipids (0,5 – 1 % mas), proteins (< 0,5 % mas, predominantly enzyme proteins) and minerals (< 0,05 % mas) (BELITZ et al., 2001; HOSENEY, 1994).

Wheat starch usually consists of about 25 % mas amylose and 75 % mas amylopectin. Amylose, with a molecular weight of about 250.000 Dalton (varying with maturity) is a long linear, helical screwed polymer linked via α-1,4 bonding and consists of about 500 to 6000 glucose monomers. There is indication that amylose also has branches, which are linked via α-1,6 bonding (SHIBANUMA et al, 1994). Amylopectin is a highly branched polymer with branches going out between every 20^{th} – 25^{th} glucose molecule. It has a huge molecular weight at about 10^8 Dalton and is primarily linked via α-1,4 bonds, but with α-1,6 bonds occurring at a rate of about 4 – 5 % mas (BELITZ et al., 2001; HOSENEY, 1994).

In human nutrition, starch is a very important energy resource. It is a very important instrument in food technology and its function lies within its ability to interact with water under the influence of heat. Wheat starch has got a typical onset gelatinization temperature that lies within 58 – 64 °C. That’s the temperature, where granular birefringence and crystallinity loss start as well as molecular order gets disrupted. Viscosity increases with each degree Celsius and starch swells more and more (HOSENEY, 1994). At about 45 °C amylose starts to come out of the starch granule and passes over into solution. This effect was estimated to be a reason for the residual gas retaining strength in dough when volume increases in the oven (SEIBEL, 2005). As temperature rises above 75 °C, starch granules and solubilised amylose swell more and more and start forming a viscous starch paste (GOESAERT et al., 2005).

If the hot starch paste is cooled, it wants to get in order again. Both amylopectin and amylose gel try to get rid of their bound water, i.e. they tend to become insoluble and microcrystalline. This effect is called retrogradation (HOSENEY, 1994).

3.2.1 THE ROLE OF WHEAT STARCH IN BREAD MAKING

Without starch, no volume expansion in dough would be possible and the bread loaf would not look and taste the same. Crumb formation is only possible with the help of starch (SCHÜNEMANN and TREU, 1993).

Starch gelatinization is a crucial factor in baking. In order to gelatinize, starch needs water. As starch is not able to bind much water at room temperature, it’s the role of the gluten to swell and provide water absorption. When gluten releases its bound water due to denaturation above 60 °C, starch is able to bind it and swell at a temperature range from 70 °C to 90 °C. Nevertheless, because of shear forces affecting starch granules during dough mixing and formation, starch can bind water at mixing temperature (up to 20 % vol) via capillary attraction, too. This mechanism is called dilatancy (SEIBEL, 2005).

It may be important to consider that bread and all other baked goods are systems with restricted water content, i.e. less water is available for starch gelatinization than needed. GHIASI et al. (1983) detected that the temperature interval typical for wheat starch gelatinization gets extended (20 – 30 °C) by low water content, sugars and also salt, i.e. gelatinization occurs more slowly (it takes more time). In addition, GHIASI et al. (1983) tried to describe how flour ingredients like gluten have an influence on starch gelatinization as well. Gluten was found to still hold back some amounts of water during coagulation and therefore delivering less water for gelatinization.

After bread baking, the loaf starts changing its sensory properties. These effects are due to water migration from crumb to crust and because of starch retrogradation and lead to the staling of bread, which is an unwanted factor. Product shelf life decreases and bread starts losing its fresh and crispy attitude within extended storage time. Exact reasons for the staling of bread are still under discussion. Amylose was stated to start its retrogradation quite after baking, whereas amylopectin needs a longer time to begin retrogradation, namely about the same time as staling; amylopectin retrogrades in a constant manner. Thus, GRAY and BEMILLER (2003) suggested amylopectin to be responsible for bread staling, but they also insisted in the consideration of other factors which could possibly play a role, like gluten-starch interaction or the redistribution of water within bread. Further researches are required.

On the other hand, starch provides sugars that are needed for yeast growth and fermentation. Special enzymes from the wheat kernel itself or added enzymes from baking agents are able to degrade sugars, like maltose, from the starch granule. These enzymes are called α- and β-amylases. In the oven, during the baking process, an initial dough temperature of about 35 °C leads to an increased amylase-activity. At about 75 °C, β-amylase gets inactivated and at about 85 °C α-amylase gets inactivated as well (MAR et al, 2007).

Furthermore, other degradation products from starch, so-called dextrins, are important for the crust colour. Under influence of heat they get a brown colour and the steam in the oven makes dextrins appear glossy (SCHÜNEMANN and TREU, 1993).

3.2.2 WHEAT STARCH AND SALT

Salt was proved to have impacts on starch gelatinization temperature. Via Differential Scanning Calorimetry GHIASI et al. (1983) were able to show an increase in gelatinization temperature and a decrease in water activity when 2 % mas salt on flour basis were added to a water-limited dough. 2 % mas of salt caused an increase of the initial deviation temperature from 56 °C to 62 °C. Nevertheless, salt concentrations higher than 25 % mas caused a decrease in gelatinization temperature compared to dough containing no salt. Consistent results were found by the use of the amylograph-method (LINKO et al., 1984). Initial and peak temperatures for gelatinization were increased the more salt was added to wheat, rye or barley dough. SPEIRS et al. (2009) suspected this effect of salt on starch gelatinization temperature as one reason for changes in bread loaf volume. A higher gelatinization temperature would give more time to the dough to expand in the oven at a higher salt level. In turn, if salt content was reduced, the final bread loaf volume may be lower. But SPEIRS et al. (2009) also stated that a higher gelatinization temperature alone may not be the only factor playing a role concerning the bread loaf volume. Wheat variety or water content, for example are important factors, too.

Starch retrogradation was reported to be affected by salt as well. LYNCH et al. (2009) baked bread and compared staling of bread when salt was omitted with bread containing 2 % mas of salt. After 120 h, the bread with no salt was much firmer than the other one. The difference was found to be significant. Their hypothesis was that salt holds back the water within the crumb, i.e. the bread remains moist and retrogradation is slowed down. Moisture was estimated to be a factor in decelerating retrogradation by the mechanism of water prohibiting protein-starch linking (HE and HOSENEY, 1990). The same authors (1991) found that bread made with weak flour got even more effected by bread firming, because the weak gluten was thought to interact stronger with starch than bread made with strong flour.

Another factor is the impact of salt on the activity of starch enzymes. Amylases are enzymes which catalyse the breakage of hydrated starch molecules. They are divided into beta-amylases and alpha-amylases, dependent on their point of action. Beta-amylase is found in all ripe wheat grains and can only attack the ends of the starch molecule by splitting off maltose sugar. The amount of alpha-amylase in ripe wheat grains is minimal, but large quantities can be found in germinated wheat kernels. Dormancy in rye kernels is shorter in time. That is the reason why rye is more susceptible to germination and thus more susceptible to alpha-amylase. Alpha-amylase is able to attack the interior of the starch molecule by splitting of dextrins. Amylases are needed in the bread baking process, but only at limited activity. High amylase activity can deteriorate dough rheological qualities by reducing too much starch to soluble saccharides. Hence, there would be not enough starch left for the gelatinization process during baking and too large amounts of dextrins would contribute to an uncontrolled crust browning (CAUVAIN and YOUNG, 2007; SCHÜNEMANN and TREU, 1993). LINKO et al. (1984)

showed a positive influence of salt on pasting properties in certain flours. Their experiment was based on the amylograph method. A level of 0,5 % mas salt on flour basis, for instance, resulted in a rise of peak viscosity in wheat flour from 600 BU to 800 BU and a salt amount of 1 % mas on flour basis lead to peak viscosity of about 1000 BU LINKO et al. (1984) mentioned that these results may be due to prolonging effects of salt on the burst of starch granules.

3.3 YEAST

Baker's yeast, lat. *Saccharomyces cerevisiae*, is classified in the kingdom *Fungi* and reproduces by budding. It can be added to dough as a leavening agent. One can find liquid, compressed, active dry and instant active dry yeast on the market (BONJEAN and GUILLAUME, 2003). The yeast cell consists out of four components: the semi-permeable cell membrane, cytoplasm, cell nucleus and vacuole.

3.3.1 THE ROLE OF YEAST IN BREAD MAKING

During dough fermentation and proof time, yeast produces carbon dioxide and ethanol out of fermentable sugars based in flour. This process is called anaerobic fermentation:

$$C_6H_{12}O_6 \ + \ \text{yeast} \ \rightarrow \ 2C_2H_5OH \ + \ 2CO_2 + \text{ATP}$$

$C_6H_{12}O_6$..........Glucose
$2C_2H_5OH$........Ethanol
CO_2..................Carbon dioxide

"Zymase", an enzyme complex inherent to yeast, catalyses this alcoholic fermentation of hexoses in wheat (SCHÜNEMANN and TREU, 1993). The resulting ethanol partly evaporates during the baking process, when the remainder contributes to the characteristic flavour of yeast dough products. According to SOUCI et al. (2008), an average of 0,17 g of ethanol can be found in 100 g of wheat bread, for example. Other yeast owned enzymes are "maltase" and "saccharase". They are sent to the outside of the yeast to cleave disaccharides and thus for providing monosaccharides to the yeast cell (MAR, 2007).

Produced carbon dioxide is retained by the dough and causes a rise in volume. Still, little is known about how dough can retain gas in its internal. A thin liquid film from the aqueous phase is thought to build up the borders around the bubble like a rubber balloon, surrounded by a gluten-starch matrix (MILLS et al., 2003; SROAN et al., 2009).

In addition, yeast has also got a rheological influence on dough. HOSENEY (1994) declared yeast having an oxidizing effect on dough as it enables it to get more elastic after 3 h of fermentation time. Further research on the mechanism is needed.

There are two possibilities in local dough processing on how yeast can be added. The first option is called “straight dough method” when yeast is mixed up with other dough ingredients already at the beginning of the process. The second possibility is to prepare a preferment out of flour, yeast and water and then adding the remaining flour and other ingredients. This procedure is known as “sponge dough method” (SCHÜNEMANN and TREU, 1993)

Yeast is quite sensitive, it is important not to overheat it, otherwise the cells would die. Cool temperatures slow down yeast activity. In practice, a stable room temperature is essential. Optimal temperature for yeast growth ranges from 24 to 26 °C, whereas optimal fermentation temperature ranges from 28 to 32 °C. Yeast feels the most comfortable at a pH between 4,0 and 5,0 (BELITZ et al., 2001). Although sugar is crucial for yeast as a food source, too much of it is counterproductive because of its osmotic effect on yeast membranes. Salt has also got osmotic impacts, but already at much smaller amounts, which is why it should be avoided to add salt to the preferment.

3.3.2 YEAST IN INTERACTION WITH SALT

As described before, salt is known for its osmotic effect. When concentrated salt or brine gets in contact with yeast, water is pressed out of the yeast cells. Yeast slightly dehydrates and has no chance to be active.

At lower salt amounts, salt has got the ability to just slow down fermentation and therefore it allows a more gentle rise of the dough. Gas production is reduced and fermentation can be controlled by the amount of salt added to the dough (SCHÜNEMANN and TREU, 1993).

Another positive aspect of slowed down fermentation is that at the end of baking time, there is still some sugar left for the Maillard reaction. This effect needs reducing sugars for the reaction with amino acids to become melanoidins. Melanoidins are the reason for the characteristic golden-brown colour and aroma of the bread crumb. According to MAR (2010) it is possible to see a difference in crust colour due to salt reduction. The crust may become brighter with less salt, as yeast is less restricted in its activity and therefore less reducing sugars are available for the browning of the crust.

On the other hand, if there is not enough salt being added, dough could become gassy and sour due to over-fermentation or over-proving. The pore diameter in bread gets too big and pore structure is not evenly distributed. (SCHÜNEMANN and TREU, 1993).

3.4 SOURDOUGH

Sourdough is another option in bread manufacturing to improve bread quality and taste. It is prepared before the bread-making process and is added to the bread flour when dough mixing starts. Its main ingredients are flour, microorganisms (for example active lactic acid bacteria and yeast) and water. The microorganisms can either result from native flour fermentation or they can also be added to the flour from a pure culture. Their main task is to produce acid, ethanol and carbon dioxide through carbohydrate fermentation, which contributes to a more spongy dough by advanced interaction of starch, gluten and arabinoxylans in presence of acid (SPICHER and STEPHAN, 1993; ARENDT et al., 2007). About 50 species of lactic acid bacteria and more than 25 different yeasts were stated to be present in sourdough (ARENDT et al., 2007), the three predominant microorganisms being *Lactobacillus sanfranciscensis*, *Saccharomyces exiguus* and *Candida milleri*.

Bread gets a characteristic acidulous aroma due to production of flavourings like lactic acid and acetic acid. Sourdough was also found to enhance product shelf life by preventing the settlement of mould fungi and unwanted fermentation by native flour organisms (SPICHER and STEPHAN, 1993).

3.4.1 THE ROLE OF SOURDOUGH IN RYE BAKERIES

For bread containing rye flour, sourdough with its acidic character is inevitable to achieve best baking and product results. A rye flour content of 20 % mas already indicates its necessity. In comparison to wheat flour, rye flour contains less starch and gluten, but more soluble sugars, pentosans and amylolytic enzymes. Thus, its gas retention capacity is less developed and no efficient gluten backbone can be built up. A low pH is able to control alpha-amylase activity and therefore starch availability. Amylases are very common in rye flour and cause a degradation of starch. If they don't get limited by a low pH, their activity gets too high and therefore not enough starch will remain for gelatinization. At rye flour of low quality, this consequence affects the resulting bread quality even more (SPICHER and STEPHAN, 1993).

Pentosans are found in the boundary layers of the wheat kernel. They are water-insoluble carbohydrates and swell by forming a gel when water is added. One can say that pentosans replace the function of gluten in concern of water-binding. Their ability to swell depends on the low pH in sourdough. During fermentation, pentosans become more soluble in presence of the sourdough (BRANDT et al., 2004). During baking, they are able to provide enough water for starch gelatinization (SCHÜNEMANN and TREU, 1993). Rye gluten proteins were found to get blocked by pentosans. That is the reason why rye gluten plays a minor role in dough forming (CAUVAIN and YOUNG, 2007).

3.4.2 THE ROLE OF SOURDOUGH IN WHEAT BAKERIES

Bakers do not necessarily need sourdough for wheat bread production because of wheat flour's excellent baking qualities. It is more or less another option, but usually their method of choice is the straight dough process. Benefits of wheat sourdough bread technique are its aromatic taste, the possibility to alter wheat crumb for a more elastic pore structure, an elongated shelf life and also nutritional aspects. Decades ago, it was more common to use a wheat sourdough, and only recently more and more bakers have been making use of this method again. Some traditional recipes of wheat bakeries still require a preferment for best results, like Ciabatta and Panettone from Italy (SPICHER and STEPHAN, 1993; HUI and CORKE, 2006).

3.4.3 SALT AND SOURDOUGH

3.4.3.1 INFLUENCE OF SALT ON ORGANISMS IN SOURDOUGH

Impacts of salt on sourdough microorganisms are undisputed and more or less due to osmotic effects on yeasts and bacteria. Their activity or rather the delivery of their metabolic products can be controlled by salt.

CAUVAIN and YOUNG (2007) mentioned a positive influence of salt on the stabilization of sourdough. By mixing a part of the salt, which is proposed to be added to the bread, already to the sourdough, acidosis and increased substance losses can be avoided.

The addition of salt is also used to increase the storage time of sourdough, because it prevents proliferation of microorganisms (SPICHER and STEPHAN, 1993). Nevertheless, this method is just an option for the baker, but it is not required.

SIMONSON et al. (2003) tried to show the impact of salt on yeast and bacteria activity in sourdough. An increase in salt (0 % mas – 3,2 % mas on flour basis) was found to come along with a decrease in growth of yeast and lactic acid bacteria. At higher salt levels, lactic acid bacteria activity was even more affected than yeast activity, but it was also found that a low salt amount (0,7 % mas on flour basis) had a stimulating effect on them. Additionally, they reported that the salt-sensitive reaction of lactobacilli differed among their various species. Homo-fermentative species were found to be more resistant to sodium chloride than hetero-fermentative species. A positive correlation between salt and temperature could be detected as well in this study.

GÄNZLE et al. (1998) came to similar results. They isolated *L. sanfranciscensis* and *C. milleri* from sourdough, put them into a Lactobacilli-friendly medium under optimal conditions and observed possible changes due to the addition of different levels of salt. As a result, they found out that growth and activity of the bacterium *L. sanfranciscensis* was inhibited at the amount of 4 % mas salt, whereas the yeast species *C. milleri* even tolerated a salt level of 8 % mas. According to BRANDT et al. (2004), an increase in salt (0 – 4 % mas on flour basis) affected acetic acid production more than lactic acid production.

3.4.3.2 INTERACTION BETWEEN SOURDOUGH ACIDS AND SALT

Lactic and acetic acid are the sourdough acids. They are produced by sourdough bacteria and contribute to the pH of the dough but also to the characteristic aroma of the baked bread (SCHÜNEMANN and TREU, 1993).

Several studies stated that a combination of salt and acid affects the dough character in a different way as if, for example, only acid or only salt alone would be present. They concluded that salt and acid somehow interact or compete with each other. Exact mechanisms are not yet understood, but some suggestions have been made:

One hypothesis was formed, saying that at decreased pH gluten gets more soluble because of an increase in electrostatic repulsion caused by the high amount of positive charges. The gluten protein unfolds and is able to bind more water, i.e. gluten swells in presence of acids. In addition, hydrophobic elements are thought to be released at the unfolding procedure, too. But intermolecular hydrophobic activity in gluten is supposed to be too low to maintain its forces in presence of so much electrostatic repulsion. This is why the gluten network gets weak in presence of acid. On the other hand, when salt gets added to the acidic dough, these hydrophobic bonds gain more importance, because salt ions are supposed to shield positive charges on gluten and therefore enabling a rise in gluten network, i.e. gluten aggregation gets stronger again (GALAL et al., 1978).

SCHOBER et al. (2003) made a research about the impacts of lactic acids in combination with sodium chloride (3 % mas on flour basis) on gluten by adding small pieces of wet gluten to liquids with various pH levels. This model study resembled the well-established “gluten swelling index”. In addition, gluten structure was observed via laser-scanning confocal microscopy. As a result, they found out that at pH 3,9 (about the pH of pure sourdough) sodium chloride caused a denser and firmer gluten aggregation than when no acid was added. Gluten became more elastic. A decrease in swelling was also observed, although a low pH level usually tends to give more water-binding ability to gluten. Similar observations were made at pH 4,5 (about the pH of sourdough bread), but with lower severity. With these outcomes SCHOBER and al. (2003) thus reaffirmed the hypothesis made by GALAL et al. (1978).

Bread dough blended with a certain amount of sourdough has got another pH than pure sourdough. It is the baker’s decision, how much sourdough he wants to add to the bread dough, but it also depends on the type of bread. Therefore, the pH of sourdough bread can vary from 4,20 (recommended level for rye bread) to 5,40 (recommended level for wheat-/grainy rye flour-/wholemeal bread) (SPICHER and STEPHAN, 1993). This is an important fact, because it was observed that different levels of pH resulted in a different degree of salt influence (TANAKA et al., 1967). The study was based on experiments with farinograph and extensograph at various pH (pH 4,2 – 5,8) and salt (0 % mas, 1 % mas, 3 % mas) levels. Acetic acid was used for acidification. As a result it was observed that the more acid was added, the less consistent was the salted dough at farinograph measurement.

TANAKA et al. (1967) suspected the loss of bound water in dough due to salt being a reason for this. Concerning the extensograph measurement, decreasing levels of pH in the salted dough resulted in doughs with increasing resistance and decreasing extensibility.

WEHRLE et al. (1997) made the same experience in concern of farinograph dough consistency when a combination of salt and lactic acid was added. At pH 4 and an addition of 2 % mas salt on flour basis, they observed a more severe decrease in consistency, development time and stability than in doughs where only salt or only acid was added.

It should be considered that TANAKA et al. (1967) and WEHRLE et al. (1997) worked with a constant farinograph water absorption level, as mentioned above. However, more reproducible in concern of current farinograph methods would be experiments using a constant consistency level (500 BU).

In addition, WEHRLE et al. (1997) investigated the influence of sodium chloride and acid on dough behaviour, using a stress rheometer. They found out that acid shortens the required mixing time because it makes the dough less stable. But when sodium chloride was added, the dough became less sensitive to overmixing. Sodium chloride also led to a softer appearance of the dough in presence of acids.

Apart from these studies, still little is known about the effects of salt on sourdough bakery itself. Possible interactions between various components of the dough (for example pentosans and enzymes) are not considered. Special baking tests with rye flour would be necessary, too.

4 OPTIONS FOR QUANTITATIVE DETERMINATION OF TABLE SALT IN FOOD

Two different ways of quantitative determination of table salt in food can be found in literature, namely via separate determination of one of its two components – sodium (Na^+) or chloride (Cl^-). With the help of simple stoichiometric equations it is possible to calculate the appropriate salt content (Equ. 1, Equ. 2).

$$NaCl\ [g] = Na^{+}[g] \times 2{,}54$$

Equ. 1

$$NaCl\,[g] = Cl^{-}[g] \times 1{,}67$$

Equ. 2

For the quantitative determination of Na^+, atomic absorption spectrometry (AAS) and atomic emission spectrometry (AES) are the methods of choice. The prepared sample is sprayed into a flame and induces a characteristic yellow colouring of the flame due to the presence of sodium. The AAS method is based on the detection of attenuation of radiation by interaction with free atoms. The AES relies on the principle of measuring the typical electromagnetic radiation of the element during its excitation. These two methods are very precise, but in practice they are often too expensive and time consuming because the samples must be prepared in advance during a long process. Further use concerning the detection of sodium content in samples is made by inductively coupled plasma mass spectrometry (ICP-MS), but this method is expensive and time consuming, too (OTTO, 2011).

A fast, accurate and cost effective alternative to AAS, AES and ICP-MS is the thermometric titration. It is a quite new method and makes use of the exothermic effect at the reaction of sodium with aluminium solution in an excess of potassium ions in presence of ammonium bifluoride solution. The temperature of the mixture is measured during the whole titration. The endpoint of the titration is then indicated by the change in temperature (KAR, 2005).

Another cost effective and more and more common method is the ion sensitive electrode (ISE) for direct potentiometric determination of sodium content in aqueous solution (KAR, 2005).

The quantitative detection of Cl^- is very often based on argentometry (i.e. titration with silver ions). A distinction is made between the methods of "*Mohr*" (direct titration with silver nitrate and potassium chromate as indicator), "*Volhard*" (back titration of excess silver nitrate with thiocyanate and iron (III) ions as indicator) and "*Fajans*" (direct titration with silver nitrate and eosin or fluorescein as indicator). In these analyses, the respective colour change serves as the endpoint indicator. On the other hand, a potentiometric endpoint determination can be made as well. Instead of silver nitrate, mercury (II) nitrate can be used alternatively for the determination of Cl^- content with sodium pentacyanonitrosylferrate as indicator ((MATISSEK and STEINER, 2006; KUNZE and SCHWEDT, 2002).

Common disadvantages of indirect determination of sodium chloride or sodium content in foods with the help of chloride can be possible inaccurate results, e.g. due to a higher amount of otherwise bound chloride (e.g. KCl as a possible salt substitute), which would be detected – in this case – as well and could therefore pretend a higher table salt or rather sodium concentration than originally added to the sample. And vice versa, foods can also contain more sodium than previously assumed by the determination of chloride content. A possible reason could again be other Na^+ - containing ingredients in the product (s. chapter 5).

Thus, this may result in a possible maximum salt concentration only, which may not represent the actual content of salt in the product. As part of the salt reduction campaign in its true sense and with the aim to reduce the sodium content in foods, salt content determination via sodium may therefore be preferred to the determination via chloride.

A very important topic is the expression of salt concentration in the product, which can refer to the percentage of salt in the fresh product or it is based on dry mass, as well as on dry mass without fat (ALBARRACÍN et al., 2011). A standardisation of these various specification opportunities would be desirable.

5 OTHER SOURCES OF SODIUM IN BREAD

The cereal grain itself naturally contains small amounts of sodium. A short overview of several sodium contents is given in Tab. 2.

Another source of sodium is tap water with a reference value of maximum 200 mg/L (Bundesministerium für Gesundheit, 2010).

Even baker's yeast contains some amounts of sodium with an average of 34 mg/100 g and a maximum of 46 mg/100 g (SOUCI et al., 2008).

Bread improver compositions and baking agents became very popular in recent years. They facilitate the baker's work and promise best product quality. Within their abilities lies the regulation of enzyme activity and baking characteristics, they stabilize fermentation and therefore improve swelling, relaxation, pore formation and acidification. Furthermore, they have an influence on colour, crisp, loaf volume, taste and product shelf life. Sodium can be found in these ingredients as well, but usually in small doses only. This is why these products should be considered in concern of the current discussion on sodium reduction. Some of the sodium containing additives will now be discussed further on:

Sodium bicarbonate (E 500) is a component of baking soda and provides carbon dioxide for dough leavening. In practice, it is particularly used in wheat products. The difference between baking soda and baking powder is that baking powder already contains acid which is needed for the release of carbon dioxide (HOSENEY, 1994).

Caustic soda (E 524) is a solution of sodium hydroxide in water and is used at the production of lye pastry, like pretzels. In this process pastry is dipped in a 4 % vol caustic soda solution before baking which brings flour proteins in solution and leads to a swelling of starch granules. This effect and the basic milieu are the reasons for the typical browning and aroma of lye pastries during baking (SCHÜNEMANN and TREU, 1993).

Sodiumstearoyl-2-lactylat (SSL, E 481) is an emulsifier for fat-in-water solutions and an outstanding humectant. It is an artificial product resulting from a chemical reaction between sodium compounds and stearin- , lactic- and polylactic acid. In the baking industry it is used for its anti-staling effects in bread and bakery goods. E 481 was found to interact with gluten and starch, providing improved, long-lasting water binding capacity. Bread loaf volume increases and the crumb structure becomes finer (CAUVAIN and YOUNG, 2007).

Sodium acetate (E 262) is the sodium salt of acetic acid and can be added to bread as preservative (EBERMANN and ELMADFA, 2008).

Overall, it was found that connection between sodium and all of the bread constituents seems to be quite weak, as all of the sodium ions could get extracted via chewing in the mouth within 12 s only. This conclusion was made when evaluating extractability of sodium from bread crumb (HEIDOLPH et al., 2011).

Tab. 2: Sodium content of wheat and rye grains and of some flour types (adapted from BELITZ et al., 2001)

grain/flour	sodium content in mg/100 g edible portion
wheat grain	7,8
wheat flour W550	2,0
wheat flour W1050	3,0
rye grain	3,8
rye flour R997	1,0

6 SALT AND ITS SENSORY IMPACT ON BREAD

Apart from its technological functions, and more important for the consumer, salt has got a very significant status for its flavouring qualities and its ability to mask off-flavours. In 1997, BRESLIN and BEAUCHAMP detected that salt is able to suppress bitterness in food products. Bread would be strongly affected under the omission of salt, it would taste insipid and the consumer acceptance would be deteriorated. Nevertheless, a reduction in salt should not be a problem, as long as it comes in stages. BERTINO et al. (1982) could show that a dietary sodium reduction may be followed by a decreased salt preference as well; so it seems that one can lower a personal preferred salt level by habituation.

Staling of bread is a very prominent effect in bread making. A definition of the word “staling” by BECHTEL et al. (1953) is “a gradually decreasing consumer acceptance of bread due to all the chemical and physical changes that occur in the crust and crumb during storage excluding microbial spoilage”.

When bread gets older, it starts losing taste, the crumb becomes harder and the crust becomes softer due to water migration from crumb to crust and because of the relative humidity from the surroundings. It was found that water activity plays an important role in bread staling. A decrease in water activity was considered to come along with an increase in duration of bread crispness (PRIMO-MARTIN et al., 2006).

Salt is known to have a decreasing effect on water activity. Hence a decrease in salt may shorten storage time and therefore consumer acceptance. But a recent study by SAMAPUNDO et al. (2010) showed that a 30 % decrease in salt and therefore an increase in water activity of white bread had no impact on colony growth rate of frequently occurring mould fungi – in this case *Penicillium roqueforti* and *Aspergillus niger*. Nevertheless, the authors admitted that their reference bread already was of low salinity (1,7 % mas on flour basis), other results in bread stability may occur in reference to bread of current salt content.

As mentioned in (s. chapter 3), more free water comes along with an increase in starch retrogradation, which is an unwanted effect (HE and HOSENEY, 1990). But when LYNCH and al. (2009) tried to measure the outcomes of different salt levels on bread staling, they could not find any significance, which means, that the impact of decreasing salt levels on storage time may be not so big. Nevertheless, they were able to state a noteworthy difference, when no salt at all was added to the dough.

7 APPROACHES TO SOLVING TECHNOLOGICAL AND SENSORY PROBLEMS OF SALT-REDUCED BREAD

Experts have already found possible solutions in order to cope with technological and sensory difficulties due to salt reduction in bread. The most common methods are listed below:

A British project on the effect of salt reduction on bread (JOHNSTON, 2010) showed that if the salt level was reduced in “no time dough” at strict and regulated production circumstances – like at optimal temperature, handling, proving and baking time, then a lower salt content would be technologically feasible. This means that the dough can be adapted to a lower salt concentration via ameliorating changeable “circumstances”, like a change in temperature or proving time. For an explanation, “no time dough” or “Chorleywood bread process” is a special method popular in Britain and Australia, where bulk fermentation is omitted via energy-intensive mixing.

The tests included salt levels ranging from 1,2 % mas to 1,7 % mas on flour basis, which – by the way – already meets or even falls below the Austrian recommendations of 1,7 % mas on flour basis. The optimal proof temperature for their tests was estimated at 27 – 30 °C. At a lower temperature (24 °C) a greater loss of loaf height could be observed the less salt was in the dough. A higher temperature (33 °C) resulted in slightly increasing problems with dough moulding the lower the salt level was and the resulting crumb structure became more and more inadequate due to increased yeast activity. To sum up, decreasing salt levels in combination with an increasing temperature were found to result in a shortening of proof time and a more and more sticky dough. In practice, proof time of dough containing 1,2 % mas salt on flour basis was five to ten minutes shorter in time than proof time of dough with 1,7 % mas salt.

1 h bulk fermentation bread with descending salt levels resulted in reduced loaf heights. In the “sponge and dough” process the dough was perceived as getting softer during rest time the less salt was in the dough, which resulted in a shorter proof time. In addition, the crumb structure had a kind of powerless appearance.

The researchers suggested keeping in mind that the yeast content could be aligned to the present salt level as well, in order to avoid uncontrolled yeast activity and therefore a higher gas production and a more open texture.

FARAHNAKY and HILL (2007) made a study on the effects of salt, water and temperature on wheat dough by the use of a farinograph and found out that possible technological problems due to a restricted salt content in bread could get compensated via water and temperature adjustment. They were able to set up an equation too, where one can pre-calculate the effects of a certain percentage of salt on consistency, hydration time (i.e. the time needed for a farinograph curve to reach maximum consistency) and total energy at certain water and temperature levels. With this tool they thought it would be possible to find out how to compensate salt reduction by changing the variable water and temperature.

Controlled yeast addition in combination with an increased proof time could be the adjustable factors in order to cope with technological and sensory problems in the whole salt reduction dilemma. An increase in proof time was found to have positive effects on bread flavour. It could lead to an improved development of fine bread aroma (SCHÜNEMANN and TREU, 1993), which may gild a possible loss of taste due to lower salt levels. This knowledge is already used in a new so-called “slow-baking” movement.

Another alternative to defuse or get rid of sensory problems due to an insipid taste would be the addition of spices, herbs, vegetable extracts or flavourings, according to MAR (2010). Furthermore, yeast extract, dried pre-ferments, whey salts and other salts like potassium chloride (KCl) are under discussion. Current investigations are underway to find out about the technological and sensory efficiency of these ingredients and nutritional safety is checked as well.

A completely different idea is to reduce the salt content in bread via heterogeneous spatial distribution of salt, developed by NOORT et al. (2010). With the knowledge that inhomogeneous distribution of salt in food can provide a more intense salty taste (MEISELMAN and HALPERN, 1973), they created doughs with various salt levels and made layers of them, in order to get alternating zones in bread with lower salt content and some with higher salt content. This process helped them to reduce salt level in bread for more than 28 % without losing its salty intensity. But it has to be considered that this method may not be an option for every bakery product and the production of such bakery good may require a large effort, as well.

8 RECENT CONSUMER ACCEPTANCE AND SENSORY TESTS

KLEINERT et al. (2009) tried to assess consumer acceptance of salt reduced bread in Switzerland. In addition they wanted to find out via a triangle-test in which dimension a trained panel would be able to notice different salt levels (1,5 % mas – 1,9 % mas on flour basis) in bread. The bread type of their choice was the typical Swiss “Ruchbrot”. In the end they came to the result that the trained panel (21 “salt-sensitive” persons in the first round, 20 in the second round) was not able to differentiate between salt levels ranging from 1,8 % mas to 1,9 % mas. Nevertheless, in comparison to their reference bread (2 % mas) and bread containing 1,6 % mas or 1,7 % mas they could perceive a significant difference.

The consumer acceptance test had 61 participants and was based on a degustation of bread containing salt levels from 1,4 % mas to 1,7 % mas on flour basis. Resulting data were analysed at the basis of a Friedman-Test. As a conclusion, there was no significant preference of a certain salt concentration. But the data also showed, that a concentration of 1,7 % mas could be significantly distinguished from a concentration of 1,4 % mas. A salt level of 1,4 % mas was found to be not enough salty, whereas bread having a salt concentration of 1,7 % mas was significantly stated to be just right.

GIRGIS et al. (2003) reported that up to 25 % less salt in bread could not get detected by their probands in a single-blind, randomized, controlled trial with 110 participants. As a result of their study they recommended a stepwise salt reduction instead of one sudden large reduction, because then a lower salt content would be more difficult to notice. In consideration of this advice it may be even possible to come down to the recommended salt level (1,7 % mas on flour basis) for bakers having a current salt content above average in their products.

A minimum detectable difference for salt content in wheat bread was tried to be found via duo-test evaluation of bread samples by a trained sensory panel. Investigators came to the result that with a control sample of 1 % mas salt content it is possible to detect a difference in salt content starting from 0,3 % mas. Bread samples with a salt content of 0 % mas and 0,7 % mas were stated to taste “floury” and “watery” and the taste of yeast stood out more in these samples. In addition, minimum threshold for salt recognition in the bread crumb was evaluated at a level of 0,16 ± 0,08 % mas based on bread (HEIDOLPH et al., 2011).

In this case, it may be of importance to underline the individual threshold for salty taste. Everyone has got his/her own personal taste and therefore preference. Nevertheless, a habituation to higher salt levels seems to be predominant in Austria when looking at the average daily salt consumption but can be diminished again by getting people gradually used to lower salt levels.

9 AUSTRIAN TYPES OF BREADS AND SMALL BAKED GOODS

Bread consumption is widely spread all over Europe and part of the culture. Particularly in Germany, France, Austria and Switzerland bread and small baked goods play an important role in the human diet. This is underlined by the large variety of breads and small baked goods; every country has its own bread specialities and manufacturing methods.

In Austria, “Codex Alimentarius Austriacus” (BUNDESMINISTERIUM FÜR GESUNDHEIT, 2010) mentions three categories of baking products: bread, small baked goods and fine bakery.

The category “bread” is divided into four sub-categories in reference to the types of flour, ingredients and preparation methods: rye bread, wheat bread, mixed bread and “other types of bread”. The term “rye bread” is only permitted for bread with a total content of more than 90 % mas rye grain products. Less than 10 % mas is allowed to derive from wheat grain products. Wheat bread is permitted to consist of less than 10 % mas Type 500 rye flour. One exception is sandwich (or toast) bread which should be made of 100 % mas wheat grain products. Mixed bread, or “brown bread” is a mixture of wheat and rye grain products. Rye mixed bread contains about 50 % mas to 89 % mas rye flour, the rest consists of wheat flour. The heading “other types of bread” includes all remaining types of bread which vary due to their ingredients, processing methods or compositions, like for example wholemeal bread, spelt bread, crispbread, pumpernickel, or bread baked in a wood-fired oven.

Basically bread consists of flour, water and salt. Other ingredients are sourdough or yeast for bread leavening and optional components like spices and spice extracts, seeds, additional starch, pre-gelatinised flour, dough acidifiers, citric or tartaric acid and their salts, milk products, sugars, edible fats and oils as well as vegetable substances rich in proteins like wheat gluten or soy flour.

The primary roll leavening ingredient is yeast, even though sometimes sourdough can be used as well. Otherwise the ingredients are the same as for bread. Additionally, eggs and egg products, dried fruits, potato and potato products and salt, seeds and spices for sprinkles on top of the rolls can be used.

A typical Austrian roll is the so-called “Semmel”, a white bread roll with more than 45 g in weight. There are several kinds of “Semmeln”, like “Kaiser-, Lang-, or Kärntner Semmeln” in reference to their appearance and manufacturing methods. They all have in common that their main ingredient is more than 90 % mas wheat flour and less than 10 % mas rye flour.

10 TASKS

Salt reduction in bread and small baked goods is currently a hot topic in Austria and the whole European Union. Bakers worry about the impact of salt reduction in connection with possible technological processing problems and they are also concerned about the consumer acceptance of salt-reduced products. As salt has influences on dough processing and baking quality, it is important for the baker to be aware of them in order to be able to handle them.

This diploma thesis is part of a project of the “Versuchsanstalt für Getreideverarbeitung (VfG)” concerning their competence development in the fields of product testing and it should give an overview on several aspects of salt reduction in bread and small baked goods.

The main objective of the practical part of this diploma thesis was divided into three main priorities:

1. Based on empirical dough rheological methods, it should be found out whether and how salt affects dough. Additionally, transferability of the empirical results on practical baking tests should be elicited.
2. Produced mixed rye-breads and kaiser rolls of four salt levels (2,5; 2,0; 1,7 and 1,5 % mas on flour basis) each should be evaluated by untrained assessors with the aim to detect whether consumers are able to identify different salt levels at all and further on, if they are able to classify salt levels in a correct way. Moreover, personal preferences should be tested as well to get an impression on how important the salty taste in bread is among consumers.
3. The actual state of salt addition in Austrian mixed rye bread (with a ratio of 70 % mas rye flour and 30 % mas wheat flour, short form “70:30”) and kaiser rolls should be tested by sampling. For this purpose about two bakeries each from every Austrian province were selected to send one mixed rye-bread and one kaiser roll for analysis. The aim of this project was to find out whether bakers are already working with the proposed salt level and if there is need for further action concerning salt reduction programmes.

11 MATERIALS AND METHODS

11.1 RAW MATERIALS

11.1.1 FLOUR

Commercially treated wheat flour (60 kg of W 700 and 60 kg of W 1600) and 60 kg of rye flour (R 960) were provided by Assmannmühlen Gesellschaft m.b.H., Guntramsdorf, Austria. Each flour type was packed up in two paper bags à 30 kg each and every single flour type was mixed before usage. Afterwards, they were stored in well-sealed plastic buckets until usage. Standard analyses of the flours came up with following “key figures” (Tab. 3).

Tab. 3: Key figures for the flours used for further analysis

	W 700*	W 1600**	R 960**
moisture [%] (Brabender®)	13,5	11,8	12,3
ash [%] (ICC 104/1) i. Ts.	0,65	1,46	0,95
amount of gluten [%] (ICC 137/1)	30,3	29,7	-
maltose [%] (Berliner)	2,0	4,6	-
falling number [s] (ICC 107/1)	-	-	174
amylogram (ICC 126/1)			
gelatinization start [°C]	-	-	54,8
gelatinization temperature [°C]	-	-	67,0
gelatinization max. [BU]	-	-	336

*used for extensogram, farinogram and kaiser roll baking test
**used for mixed rye-bread baking test

11.1.2 OTHER INGREDIENTS USED IN BAKING

- Tap water
- Commercial cooking oil
- Organic dough acidifier (“Biosauer Hell”; ingredients: dried organic rye whole-grain sourdough, acidifier lactic acid; art. nr. 02563; STAMAG Stadlauer Malzfabrik GesmbH, Austria; YOM: 2010)
- Baker’s yeast (Ottakringer Hagold Hefe GmbH, Austria; YOM: 2011)
- Baking agent (DIAGOLD, ingredients: wheat flour, sugar, emulsifier soy lecithin, pre-gelatinized wheat flour; art. nr. 01361; STAMAG Stadlauer Malzfabrik GesmbH, Austria; YOM: 2010)
- Sodium chloride (AnalR Normapur, art. nr. 27810.364; VWR, Belgium, YOM: 2010)

11.2 RHEOLOGICAL METHODS

Rheological methods are usually designed to provide information on the workability and quality of certain flours, together with flour characteristics and baking tests. Advantages of these methods are a small necessary sample quantity and a rapid implementation in comparison to baking tests, for example. Rheological methods are subject to standardization by either ICC, AACC or other grain analytical organisations.

11.2.1 EXTENSOGRAM METHOD

11.2.1.1 PRINCIPLE

This method is based on ICC Standard Nr. 114/1, Brabender® Extensograph, confirmed in 1972 and revised in 1992. Preparation of the dough samples is based on the well-established Brabender® version. References are found in the operating instructions for extensograph, extensograph software and extensograph correlation programme by Brabender® OHG, Duisburg.

The extensogram method is an empirical dough rheological experiment to assess baking properties of wheat or spelt flour. The general goal of this method is to record resistance to extension and extensibility of the dough. In addition, it can be used for investigations about the influences of additives (like ascorbic acid) on the flour.

At the beginning of the analysis, flour, water and salt are mixed in a 300 g farinograph mixer under standard conditions to get a dough. The dough is divided into two samples à 150 g each for repeat determination. Each dough sample gets formed to a strand and is stored in a chamber for a defined time. After that period it gets stretched via a mechanical hook until rupture. In the meantime, a computer software records all data obtained from the analysis and draws a graph which provides information on the physical properties of the dough. After the analysis, the dough is collected, a strand is re-formed and it is put into the chamber again until the next measurement after further 45 min. This process is repeated twice.

Following important rheological data can be collected via the extensograph method:

Water absorption [%] is the amount of water needed to get a dough consistence of 500 ± 20 BU with an accuracy of 0,1 % and is read off the burette after the dough mixing process.

Energy [cm²] is calculated from the "area under the curve" and provides information about the total power of dough and the energy needed to stretch the dough (SEIBEL, 2005).

Resistance to Extension [BU] is determined by the height of the curve measured at 50 mm from its origin with an accuracy of ± 1 BU. It indicates the oxidation status of the dough (HOU, 2010) and gives information on the ability of dough to resist against extension (SEIBEL, 2005).

Maximum Resistance to Extension [BU] can be chosen alternatively or additionally to the value "resistance to extension". It is determined by the maximum height of the curve and has an accuracy of ± 1 BU.

Extensibility [mm] is determined by the moment the hook touches the dough until dough rupture and is measured on the baseline of the graph with an accuracy of ± 1mm.

Ratio Number is the quotient of "resistance to extension" and "extensibility" and characterises behaviour at proving.

Ratio Number [max.] is an alternative or additional value for "ratio number". It is determined by the quotient of "maximum resistance to extension" and extensibility.

The values from energy, resistance to extension, (maximum) resistance to extension, extensibility and ratio number (max.) are automatically determined by the Brabender® software.

In the end six graphs of different colours, based on measurements after different proof times, are recorded on the desktop (Fig. 1). Values are applied on a normed resistance-extensibility-diagram with the value "extensibilty" [cm] on the x-axis against resistance [BU] on the y-axis.

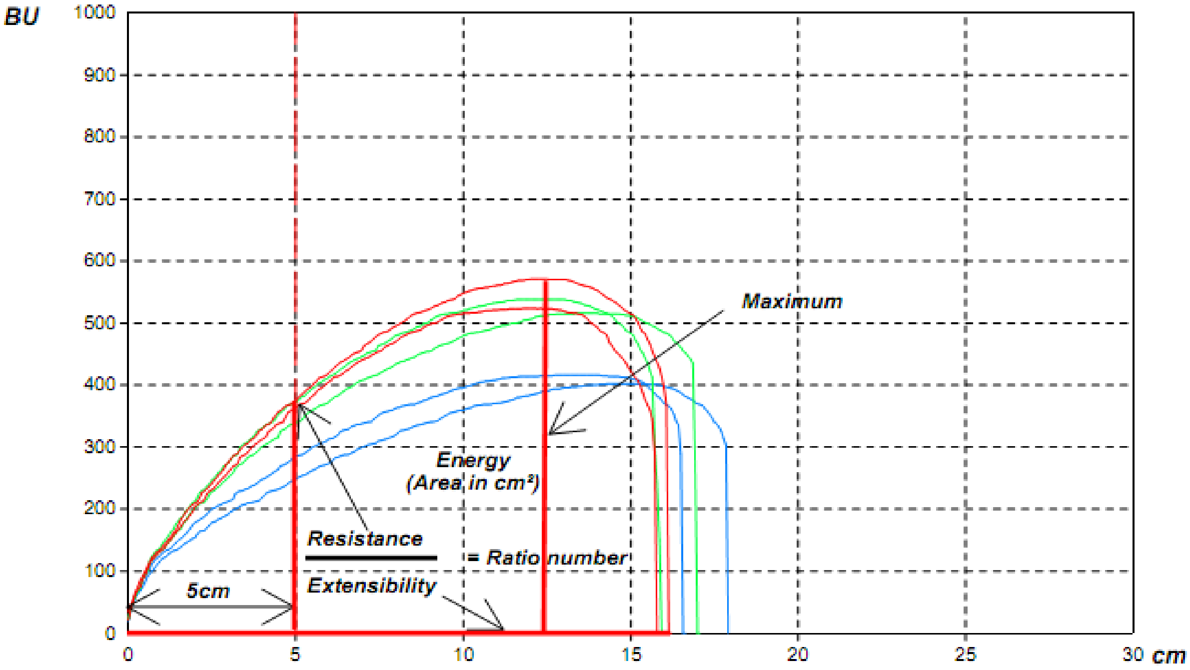

Fig. 1: Extensogram interpretation data (shown with the help of the bigger red curve)

blue graphs (after 45 min)

green graphs (after 90 min)

red graphs (after 135 min)

11.2.1.2 MATERIALS

1. Sodium chloride AnalR Normapur; art.nr. 27810.364; VWR, Belgium (2010)
2. Aqua dest. from own production (for general laboratory analysis, device: GFL Linder, nr. 112277507 J, 2007)

11.2.1.3 EQUIPMENT

- Inframatic NIR apparatus (8100, Perten Instruments, Germany, 1992)
- Precision scale (PB 602-S FACT, Mettler, Vienna, 2002, accuracy: ±0,02 g)
- Farinograph 300 g + burette (810104, Brabender®, Germany, 1982)
- Extensograph-E (860703, Brabender®, Germany, 2011, accuracy: 9 % MW = ± 14,4, based on extensibility at repeat determination)
- Circulation thermostat (T150E, Brabender®, Germany, 1987)
- Spatula
- Spoon
- Shovel
- Measuring cups
- Glass rod
- Timers

11.2.2 FARINOGRAM METHOD

11.2.2.1 PRINCIPLE

This method is based on ICC Standard Nr. 115/1, Brabender® Farinograph, confirmed in 1972 and revised in 1992. References are found in the operating instructions for farinograph, farinograph software and farinograph correlation programme by Brabender® OHG, Duisburg.

The principle of a farinograph measurement is the assessment of the reaction of flour to dough formation. It is measured by resistance of dough to the kneading hooks of the farinograph mixer at constant mixing speed and gives information on appropriate mixing time, mixing tolerance and dough development (SEIBEL, 2005). Values are applied on a normed energy-time-diagram with the value "time" [min] on the x-axis against consistency [BU] on the y-axis (Fig. 2). In addition, the flour's ability to absorb water can be assessed as well.

Following data can be obtained via the farinogram graph (Fig. 2):

Water absorption [%] is the amount of water that leads to a dough consistency of 500 BU (± 20 BU). The accuracy of this value is ± 0,1 % and gives information on dough yield.

Development time [min] starts with the addition of water and ends when the farinogram curve reaches its highest point. This value has an accuracy of ± 0,1 min and it provides data on the optimum mixing time.

Stability [min] is a period of time that starts when the upper edge of the augmenting farinogram curve exceeds the 500 BU line and ends up when the upper edge of the falling farinogram curve falls below the 500 BU line. Stability has an accuracy of ± 0,1 min and is used to show how long dough can resist to high mechanical stress without losing its properties (mixing tolerance).

Degree of softening [BU] is described as the difference between the centre of the farinogram curve at the end of dough development and the centre of the farinogram curve 12 min after the end of "development time" and is stated with an accuracy of ± 1 BU. It provides information on the severity of dough softening to mechanical stress when the dough gets over-mixed.

Quality number [mm] is defined as the length of the time axis which starts with the addition of water and ends up when the height of centre of the farinogram curve (green curve) gets 30 BU lower than the height of the centre of the farinogram curve at “development time”. It permits easy and rapid evaluation of the farinogram.

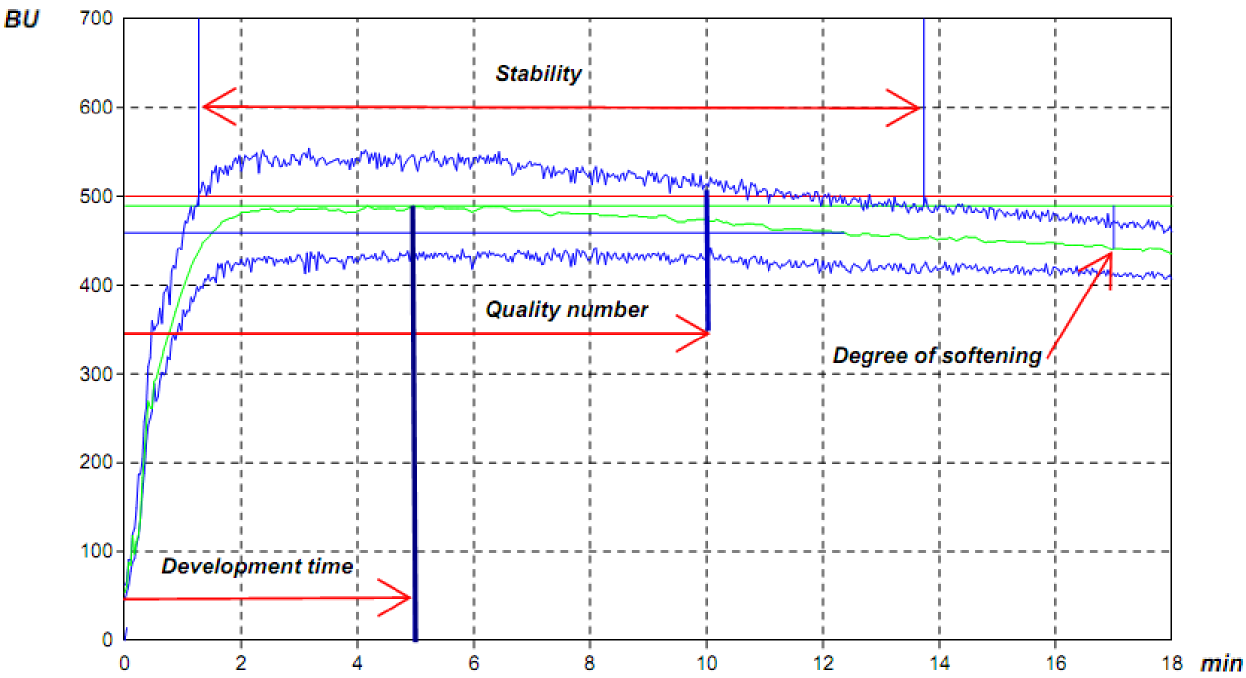

Fig. 2: Farinogram interpretation data

11.2.2.2 EQUIPMENT

- Inframatic NIR apparatus (8100, Perten Instruments, Germany, 1992)
- Precision scale (PB 602-S FACT, Mettler, Vienna, 2002, accuracy: ±0,02 g)
- Farinograph 50 g + burette (810105002, Brabender®, Germany, 1992, 25 % MW = 1,13 for development time at repeat determination)
- Circulation thermostat (T150E, Brabender®, Germany, 1987)
- Spatula
- Spoon
- Shovel
- Measuring cups
- Glass rod

11.3 BAKING TESTS

11.3.1 PRINCIPLE

Baking tests provide information on the baking quality of flours under standardised conditions. In addition, they are also used to show practical implementation options for new or modified recipes or ingredients (BELITZ et al., 2001). Processing quality of the dough and the quality of the baked products are assessed by trained persons on the basis of determined evaluation criteria. Tab. 4 shows evaluation criteria for the baking protocols used for evaluating salt-reduced mixed rye-bread and kaiser rolls. Baking tests were developed by the VfG in 2011.

Volume yield of the baked product is determined via the Chopin® volumeter (Fornet, Chopin, France). The principle of this method is the displacement of rapeseeds or other small seeds by the volume of the baked good. The volumeter is composed out of two sealable metal jars which are connected to each other via a scaled and transparent cylinder. One jar is designed for the measuring of bread, the other one is for measuring rolls. The apparatus is mounted on a rotatable frame. One of the jars always contains a plastic dummy inside with a volume of 1500 cm³. This is the empty volume. The baked product is put into the jar on top of the apparatus, while the seeds are stored in the jar on the bottom. When the apparatus is turned upside down, the seeds trickle through the cylinder into the jar with the bread and they ascend to a certain height of the cylinder, the measured volume. The volume yield of the baked product is then calculated via an equation (Equ. 3).

$$\boldsymbol{V_{bp} = V_m - V_e}$$

Equ. 3

V_{bp} .... *volume of the baked product [cm³]*

V_m .... *measured volume on the volumeter [cm³]*

V_e .... *empty volume (=1500 cm³)*

Tab. 4: Evaluation criteria for the baking protocols

MIXED RYE-BREAD BAKING TEST		KAISER ROLL BAKING TEST	
dough evaluation scheme		**dough evaluation scheme**	
surface	normal – slightly dry – dry – slightly moist – moist – smeary/very moist	surface	slightly moist (normal) moist – sticky – dry
dough structure (elasticity)	normal – good stand – slightly short – short – slightly smooth – smooth/ weakening	dough structure (elasticity)	normal – plastic/ smooth/ slightly short – slightly weakening/short – weakening/slightly tenacious – runny/tenacious
processing properties of dough	very good – good – satisfactory – poor – not processible	processing properties of dough	very good – good – satisfactory – poor – not processible
evaluation of bread		**evaluation of roll**	
form, appearance	flat – normal – round	form, appearance	flat – normal – high
browning	low – normal – strong	browning	low – normal – strong
character of crust	low – normal – strong – hard – soft – shell	break and shred	very good – good – satisfactory/normal – insufficient (narrow – wide)
crumb porosity, crumb structure	compact – normal – open grain – bread streaks – crack – moist – dry	crumb porosity	fine – medium – open grain – even – uneven
crumb elasticity	low – normal – good		
smell and taste	normal – foreign (incl. explanation)	smell and taste	normal – foreign (incl. explanation)
evaluation of volume yield [ml/100 g flour]	> 340 = very good 320 – 339 = good 300 – 319 = satisfactory 280 – 299 = poor < 280 = insufficient/ unsatisfactory	evaluation of volume yield [ml/100 g flour]	> 740 = very good 700 – 739 = good 650 – 699 = satisfactory 600 – 649 = poor < 600 = insufficient/ unsatisfactory
baking quality	very good – good – satisfactory – poor – insufficient/unsatisfactory	baking quality	very good – good – satisfactory – poor – insufficient/unsatisfactory

11.3.2 EQUIPMENT

- Spiral kneader (AD 23/8/4, Oase, Germany, 1996)
- Dough divider and rounder (DOFG 422/5413, Fortuna, Germany, 1982)
- Kaiser roll maker (Komet, Germany,1983)
- Baking oven and fermentation chamber (Condo C-2-68, MIWE, Germany, 1996)
- Volumeter (VPP 160, Tripette + Renaud, France, 1996, accuracy: ± 50 cm^3 / graduation of scale: 10 cm^3)

- Precision scale ± 0,01 (PT 210, Sartorius, Germany, 1982)
- Bowls and cups
- Shovel
- Spatula
- Timers
- Baker's linen
- Fermentation basket
- Bread tins
- Baking tray
- Wooden tray
- Brush

11.4 SENSORY EVALUATION OF BREAD AND ROLLS

11.4.1 SENSORY METHOD

The sensory method is based on a hedonic ranking test for untrained test persons. Advantages of this kind of test are the simplicity and a quick feasibility in relation to instructing assessors and data processing (LAWLESS and HEYMANN, 2010). There is no need for trained test persons or a sensory lab. The degustation can take place outside sensory labs, too. Disadvantages can be that the results of various tests can't be compared to each other (DERNDORFER, 2008).

Hedonic ranking tests are the method of choice when trying to rank three or more samples due to a single specified attribute or due to personal preference. Only one attribute should be assessed at once. The ranking test can be used to find out whether the assessors can find a difference between the samples or not (BUSCH-STOCKFISCH, 2002). All samples are presented simultaneously to the test person

For both, the mixed rye-bread and the kaiser roll test, the questionnaire is the same (s. appendix 18.3). It is composed out of two questions. The first question of the sensory evaluation is based on a hedonic ranking test concerning product preference. With the help of this test it is possible to compare more than two samples with each other by ranking them. The test person ranks the products from number one (most preferred) to number four (least preferred). If the person cannot find a preference in between some samples, then he or she can also rank several samples with the same number (BUSCH-STOCKFISCH, 2002; DERNDORFER, 2008). This has to be considered at the evaluation of the test results, when the cross sum of all four ranks should be 10 (1+2+3+4=10; or 1+2,5+2,5+4=10).

The second question is based on a sensory evaluation concerning product saltiness, with number one being the least salty product and number four being the most salty one. This method is based on a ranking test for any attribute.

11.4.2 STATISTICAL ANALYSIS OF DEGUSTATION PROTOCOLS

The statistical programmes used for the analysis are SPSS® 13.0 for Windows and MS Excel 2010®.

The statistical analysis of the received data from the degustation protocols is made via the *Friedman* test, followed by *Wilcoxon* and *Nemenyi's* post hoc test, if a significant difference could be found before, because the Friedman test alone cannot give information on between which pairs of products a significant difference really exists.

The Friedman test is a method, which is often used to analyse ranking tests. It is a non-parametric test that elicits possible statistically significant differences concerning a specific attribute in between the samples. It is used for analysis of variance on ranks. The null hypothesis (H0) assumes no significant difference in between the samples. The alternative hypothesis (H1) suggests a significant difference in between the samples with a p-value of less than 0,05 (LAWLESS and HEYMANN, 2010).

The *Wilcoxon* significance is calculated with the help of SPSS® 13.0 for Windows. It is a test for pairwise comparison of products which are depending on each other (BUSCH-STOCKFISCH; 2002).

The *Nemenyi's* test is made by hand with prior calculation of the critical difference (Equ. 4) and calculation of mean ranks for each sample. The Excel function CHIINV(possibility %; degrees of freedom) was used to get $(\chi^2)_{crit}$. The possibility was therefore set with “1 %” and the degrees of freedom were set with (c – 1 = ”3”).

The *Nemenyi's* post-hoc test is used for multiple comparisons after significance of Friedman test (JAPKOWICZ and SHAH, 2011)

For comparability reasons, the ANOVA test followed by post-hoc *Tukey* for multiple comparisons is used, too, to confirm proper outcomes of the consumer acceptance evaluation (BUSCH-STOCKFISCH, 2011).

$$\boldsymbol{CD} = \sqrt{\frac{\boldsymbol{c}(\boldsymbol{c}+\mathbf{1})}{\mathbf{6}\boldsymbol{r}} \times (\boldsymbol{\chi}^{\mathbf{2}})_{\boldsymbol{crit}}}$$

Equ. 4

CD .... *Critical difference*
c .... *number of columns (product samples)*
r .... *number of data rows (assessors)*
$(\chi^2)_{crit}$ .... *threshold of the urged significance level*

11.5 POTENTIOMETRIC DETERMINATION OF CHLORIDE FOR THE CALCULATION OF SALT CONTENT

11.5.1 PRINCIPLE

Based on ASU L 17.00-6 ("Amtliche Sammlung von Untersuchungsverfahren" according to § 35 LMBG, Germany) the determination of chloride by potentiometric measurement is one possibility to calculate NaCl-content in bakery products in [% mas] or [g] per 100 g of baked product.

In this case, the test sample which is dried in the drying oven and finely ground with the Knifetec milling apparatus, gets extracted with aqua dest and ethanol absolute. The chloride is then titrated with $AgNO_3$-solution in the milieu of nitric acid sour solution. The consumption of $AgNO_3$ is measured via potentiometric end point determination and the value is then used for further calculations on the salt content in [% mas] based on 100 g of dry mass (Equ. 5). This calculation is made automatically by the titroprocessor (Titrino plus by Metrohm®) (Fig. 3).

The proportion of salt in [% mas] based on 100 g of bread or small baked good at current measured moisture is calculated by using another equation (Equ. 6).

To ensure a better comparability in between the samples which always have different moistures, standard moisture for baked products was determined which was set at 40 % for bread and 30 % for small baked goods and on the basis of this standard moisture, salt content was calculated in [%mas] from 100 g of the “fresh” baked good (Equ. 7).

Another equation is made to calculate the amount of salt added to 100 g of flour (Equ. 8). It has to be considered that the results of this equation can only provide approximate values, as the exact amounts of flour used for each recipe are unknown. Thus, the calculations are based on an amount of 60 % or respectively 70 % as these amounts are estimated as a standard.

$$\boldsymbol{NaCl\ (i.Tr.) = EP_{01} \times (\frac{M}{10}) \times f \times t \div m}$$

Equ. 5

NaCl (i.Tr.)........*salt content in the dry mass of the baked good [% mas]*
EP_{01}..................*consumption of $AgNO_3$-solution until the first equivalence point*
M/10...................*molar mass/10 = 5,8443*
f...........................*factor 0,1 (for %)*
t...........................*titre of the $AgNO_3$-solution*
m.........................*sample weight in [g]*

$$\boldsymbol{NaCl\ (F) = \frac{NaCl\ \ i.Tr.\ \ \times (100 - F)}{100}}$$

Equ. 6

NaCl (F)............*salt content of the baked good at current measured moisture [% mas]*
NaCl(i.Tr.)........*salt content in the dry mass of the baked good [% mas]*
F..........................*moisture (Brabender®)*

$$\boldsymbol{NaCl\ (StF)} = \frac{\boldsymbol{NaCl\ (Tm) \times (100 - StF)}}{\boldsymbol{100}}$$

Equ. 7

NaCl (StF)........*salt content at standard moisture [% mas]*

NaCl (i.Tr.)........*salt content in the dry mass of the baked good [% mas]*

StF........................*standard moisture (i.e. 40 % for bread and 30 % for small baked goods)*

$$\boldsymbol{NaCl\ (flour)} = \frac{\boldsymbol{NaCl(StF)}}{\boldsymbol{Flour}} \times \boldsymbol{100}$$

Equ. 8

NaCl (flour)........*amount of salt based on flour [g/100g]*

NaCl (StF)........*salt content at standard moisture [% mas]*

Flour....................*amount of flour [% mas] used in the recipe*

11.5.2 MATERIALS

- Titrant: silver nitrate solution c($AgNO_3$) = 0,1 mol/L; Carl Roth; Roti Volum; Charge 06460511; Art. Nr. CN66.1; Karlsruhe, Germany
- Nitric acid c(HNO_3) = 2 mol/L;
- Ethanol absolute 99,8 % vol; Austro Alco, Spillern, Charge: AAAH-5020-07025-080210
- Aqua deion., water for chromatography, Merck, Darmstadt; HC824132; 1.15333.2500
- NaCl-solution = 0,1 mol/L (Titer, 20°C, Convol Normadose; 24.1.11, Fontenay-sous-Bois, France; Ref : 32064.600)

11.5.3 EQUIPMENT

- Drying oven semi-automatic (HA 4223, Brabender®, Germany, 1996)
- Metal cups
- Analytical scale (BP 1105, Sartorius, Germany, 1986)
- Weighing boat
- Laboratory sample mill (Knifetec, Foss, Germany, 2002)

- Magnetic stirrer and magnetic stirring bar
- Titroprocessor + potentiometer + silver electrode (Titrino plus 848, Metrohm, Germany, 2010), (Fig. 3)
- Beakers, 200 mL
- 1000 µL Eppendorf pipette

Fig. 3: Titroprocessor “Titrino plus 848”by Metrohm®

12 TESTING PROCEDURE

Prior to the experiments, the temperatures of the devices were checked. They all had the required temperature of 30 ± 1 °C. The devices were calibrated before the start of the tests.

12.1 EXTENSOGRAM METHOD

The test was based on four repeats per salt level and was divided into four rounds with eight samples per round.

12.1.1 DOUGH PREPARATION

Moisture content of wheat flour “W 700” was measured with the PerCon Inframatic 8100 and resulted in a moisture of 13,5 %. The equivalent amount of wheat flour in reference to a moisture basis of 14 % was determined with the help of a conversion table (ICC-Standard Nr. 114/1) which is based on an equation (Equ. 9).

Thus, an amount of 298,3 ± 0,1 g flour for all of the samples was weighed into each plastic bowl.

The calculated amounts of salt (Tab. 5) were separately weighed into a small metal bowl and carried over into labelled plastic measuring cups. The net weight was accurate ± 0,1 g.

Afterwards, about 48 % of distilled and tempered water from the farinograph burette was put into the measuring cup in order to dissolve the salt. The mixture was stirred with a glass rod so that the salt crystals could dissolve faster. The flour was poured into the 300 g farinograph mixer and after 1 min of mixing the prepared salt -water solution was funnelled into the apparatus through the front corner on the right side without stopping the process. During the next minute the water was adjusted by using the burette in order to get a dough consistency of about 500 BU. This could be observed via the analogous graph of the farinograph kneader.

Then the kneading process was stopped for 5 min. The walls of the mixer were cleaned with a spatula and a cover was put onto the top of the mixing bowl. After the break, the fine adjustment with water to get a dough consistency of 500 BU was continued for another minute and later the dough was kneaded for a last minute, without more water being added. Meanwhile, the water absorption rate in [%] was read off the burette, which was then filled up and prepared for the next dough sample. The process was stopped and the dough was removed from the apparatus. Two portions of dough, each at 150 ± 0,5 g were weighed on a Brabender® scale and each portion was put into the extensograph balling unit to form a ball. Subsequently, the dough ball was formed in a dough roll in order to get a dough strand of cylindrical shape, which was placed in the middle of a special cradle and fixed on both ends with two dough clamps. The two dough duplicates were stored for 45 min in a humidified chamber at a controlled temperature of 30 ± 1 °C. This procedure simulated the proving time of the dough in order to let gluten relax.

$$\boldsymbol{corrected\ amount\ of\ flour}\ [\boldsymbol{g}] = \boldsymbol{a} \times \frac{\mathbf{100\% - 14\%}}{\mathbf{100\% - \boldsymbol{mc}}}$$

Equu. 9

a .... *amount of flour needed for the analysis [g]*
14 % .... *theoretical moisture content of the flour*
mc .... *analysed moisture content of the flour [%]*

Tab. 5: Calculated extensogram salt amounts based on determined salt levels

salt level [% mas] on flour basis	calculated amount of salt [g]
0,0	0,0
1,0	3,0
1,5	4,5
1,7	5,1
2,0	6,0
2,5	7,5

12.1.2 MEASURING PROCESS

After the first 45 min, one of the two dough duplicates was taken out of the chamber and it was placed on the tray holder arms of the extensograph. Start buttons on the monitor and on the extensograph were pushed in order to initiate the measurement. The dough was stretched by a mechanical hook at a constant speed until it tore apart (Fig. 4). A curve on a graph was recorded on the computer to obtain information about the rheological properties of the dough. Dough pieces were collected, a strand was reshaped as described before and the sample was stored in the chamber for another 45 min. In the meantime the measurement of the second sample was started to get a repeat determination.

Altogether, the dough samples got stretched three times each within 135 min: the first measurement was taken after 45 min (blue curve), the second after 90 min (green curve) and the third measurement was after 135 min (red curve). In the end the dough was dispensed and the curves were corrected on the monitor. The resulting data were evaluated via Brabender® software.

Fig. 4: Stretching the dough sample until rupture

12.2 FARINOGRAM METHOD

12.2.1 DOUGH PREPARATION

Each investigation was performed as duplicate.

Flour samples were prepared like in the extensogram method, but this time an amount of 49,7 ± 0,1 g flour was weighed into each plastic bowl, set off against a moisture basis of 14 % and in reference to the conversion table (ICC-Standard Nr. 114/1). Determined amounts of salt (Tab. 6) were weighed into a small metal bowl (with an accuracy of ± 0,01 g) and carried over into labelled glass measuring cups.

Tab. 6: Calculated farinogram salt amounts based on determined salt levels

salt level [% mas] on flour basis	calculated amount of salt [g]
0,0	0,00
1,0	0,50
1,5	0,75
1,7	0,85
2,0	1,00
2,5	1,25

12.2.2 MEASURING PROCESS

In the run-up of each measuring process at different salt levels, a titration was performed to assess the amount of water needed to get a consistency of about 500 BU.

At the measurement itself, the assessed amount of water was let out of the farinograph burette into the glass measuring cup and mixed with a glass rod in order to get the salt into solution. The flour was poured into the 50 g farinograph mixer, the machine was started and the flour was premixed for one minute. The measurement was started by a click on the programme. After that, salt-water solution was immediately funnelled into the mixer through the front corner on the right side. The walls of the mixer were cleaned with a spatula during kneading processing in order to get a homogeneous dough mass. After a drop in the curve was clearly visible, the device was let on the run for further 12 min or until the upper edge of the falling curve fell below the 500 BU line. The programme and the mixer were stopped no later than after 30 min. After that, the dough was removed and the mixer was cleaned and dried for the next measurement.

12.3 BAKING TESTS

12.3.1 MIXED RYE-BREAD PREPARATION

Fig. 5 gives a short overview on the manufacture of mixed rye-bread.

Four dough samples with different salt contents each (2,5; 2,0; 1,7 and 1,5 % mas NaCl on flour basis) (Tab. 7) were prepared with the help of a standardised recipe for mixed rye-bread with a flour ratio of 70:30 (Tab. 8).

The two higher salt contents (2,0 and 2,5 % mas) were chosen due to current salt amounts added by bakers. 1,7 % mas NaCl on flour represented the salt reduction goal for bread and small baked goods in Austria and a salt content of 1,5 % mas on flour basis should show whether this amount is still technologically feasible.

All of the ingredients were separately weighed in into several cups and baskets before usage with an accuracy of ± 0,1 g. 1500 g of tap water with a temperature of 15 ± 1°C were then poured into the spiral kneader bowl. Yeast was suspended in the water with a wooden spoon. Afterwards, flour, dry sour and salt were added and the mixing process was started. After five minutes of mixing at low speed, the dough was carefully taken out of the mixer by using a spatula. Small amounts of rye flour were used in order to handle the sticky dough. The dough was rolled together, wrapped up in a plastic cover to prevent it from drying out and given a rest for exactly 20 min at controlled and constant dough temperature of 26 ± 1 °C.

After bulk fermentation time of 20 min, the dough was weighed and cut in half. One half was divided into two pieces again to get two dough pieces representative for 500 g of flour, each. These two dough pieces were then used to form two tin breads. From the other half, 1175 g were weighed to form a bread loaf and get a final after-baking weight of about 1000 g. The remainder of the dough was discarded. In the end there were three pieces of determined weights (Fig. 6). Each dough piece was handed up and folded to get the end of the dough piece into the middle of the bulk product. In the end, the loaf was handed out for a second time, then wrapped up again and given a proof time of another 20 min.

After the proof time, the dough pieces were thrown into either tins, which were oiled with cooking oil before, or into the floured fermentation basket and put into the rest cabinet for 50 min at constant temperature of 35 °C and a relative humidity of 85 %.

When fermentation time was over, the bread loaf was taken out of the fermentation basket, the two tin breads were stippled three times each and they were all put into the preheated oven at a start temperature of 250 °C. After 2 min, the steam damper was opened in order to let steam out of the oven. The temperature of the oven was made falling and after 15 min a temperature of 200 °C was reached and kept for further 35 min. In the end, bread was taken out of the oven and sprayed with water to get a certain gloss of the crust.

All breads were prepared at the same standardised scheme to guarantee best comparability.

Tab. 7: Amounts of added salt for mixed rye-bread baking test

amount of salt added in [% mas] on flour basis	amount of salt added [g]
2,5	50
2,0	40
1,7	34
1,5	30

Tab. 8: Recipe for mixed rye-bread

ingredient	amount [g]
water	1500
rye flour R960	1400
wheat flour W1600	600
dry sour	120
yeast	60
salt	30 – 50

raw materials	flour, tap water, salt, etc.
mixing	5 min at „low speed“
bulk fermentation	roll together, wrap up in plastic, bulk fermentation time: 20 min
weighing, cutting, forming	forming of dough pieces: hand out, then fold and hand out again
proving	wrap up in plastic , proof time: 20 min
dough forming	put dough pieces into tins or dough rising baskets
fermentation	50 min, 85 % relative humidity, 35 °C
baking	50 min, 250 °C start temperature with falling degrees, after 15 min at 200 °C

Fig. 5: Standard scheme for the manufacture of mixed rye-bread

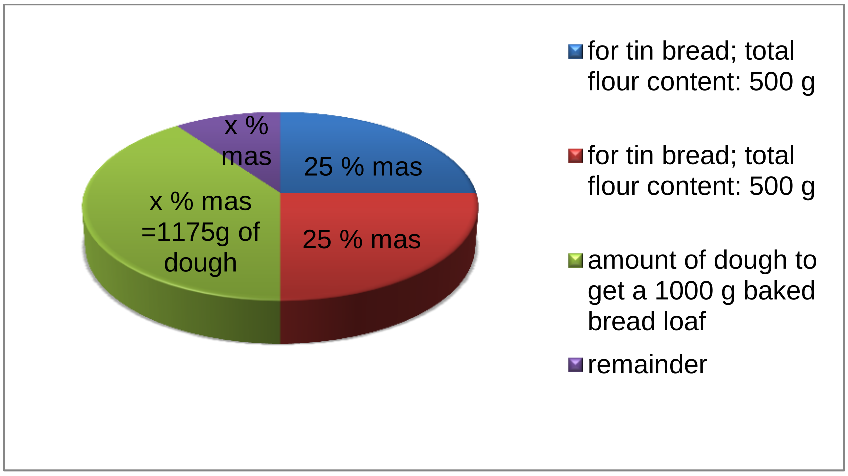

Fig. 6: Cutting scheme for bread loaf preparation

12.3.2 KAISER ROLL PREPARATION

Fig. 7 gives a short overview on the manufacture of kaiser rolls.

Four kaiser roll dough samples with different salt levels each ranging from 1,5 % mas to 2,5 % mas salt on flour basis (Tab. 9) were prepared with the help of a standardised recipe for 30 kaiser rolls (Tab. 10.). All of the ingredients were separately weighed in into several cups and baskets before usage with an accuracy of ± 0,1 g. At first, oil and tap water were poured into the mixer. The temperature of the added tap water was 15 ± 1 °C. Then the yeast was suspended in the fluid and afterwards baking agent, flour and salt were added, too. The ingredients were at first mixed with the spiral kneader at low speed for 2 min. After 2 min the dough was pushed together with a spatula and kneaded for another 5 min at high speed. Then the dough was taken out of the spiral kneader, it was moulded and wrapped up in plastic foil. Bulk fermentation time was determined with 20 min.

After bulk fermentation time, the dough got divided and rounded in the roll divider and rounder. The dough pieces were covered with baker's linen and got an overhead proof of exactly 12 min. After this, every dough piece was marked with the kaiser roll marker and they were put onto a floured wooden board with the star on the bottom. The wooden board was then pushed into the rest cabinet for 30 min at a constant temperature of 35 ± 1 °C and a relative humidity of 85 %.

After the final proof, the dough pieces were put onto the baking sheet with the star on top and the baking sheet was placed in the oven for 19 min at a temperature of 225 °C.

Like at the manufacture of mixed rye-bread, all kaiser rolls were prepared at the same standardised scheme.

Tab. 9: Amounts of added salt for kaiser roll baking test

amount of salt added in [% mas] on flour basis	amount of salt added [g]
2,5	27,5
2,0	22
1,7	18,7
1,5	16,5

Tab. 10: Recipe for 30 kaiser rolls

ingredient	amount [g]
wheat flour W700	1100
water	634
yeast	55
standard baking agent	22
cooking oil	11
salt	16,5 – 27,5

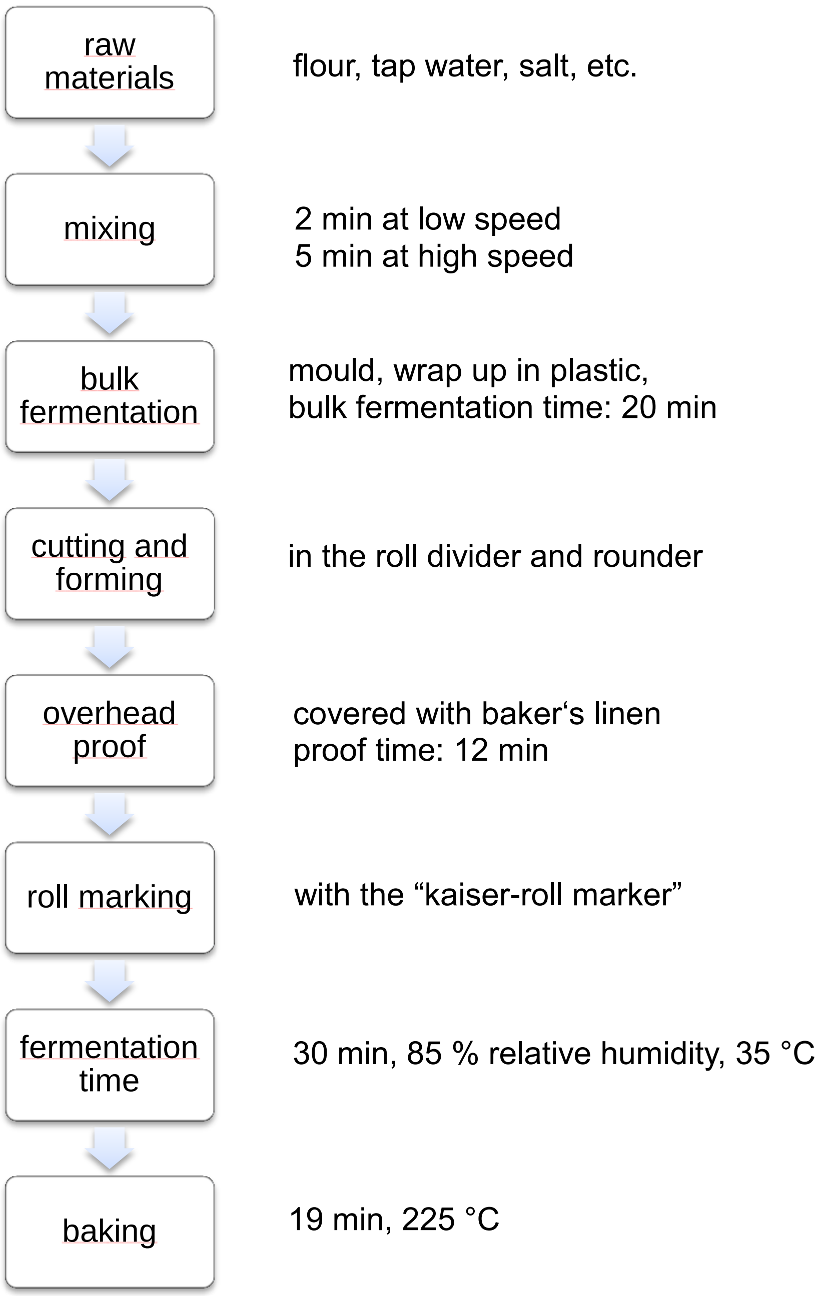

Fig. 7: Standard scheme for the manufacture of kaiser rolls

12.3.3 EVALUATION OF BAKED PRODUCTS

The classification of the baking properties was carried out according to the evaluation criteria mentioned in chapter 11.3.1. The baked goods were evaluated by three trained persons.

Evaluation of dough was made during every processing step.

Mixed rye-breads and kaiser rolls were evaluated about 1 h after the baking process. One baked product of each charge was cut in the middle (Fig. 8). Form, browning, break and shred as well as crumb and crust structure were optically evaluated. Crumb elasticity was determined through pressing one thumb into the crumb and observing the ability of the crumb to regain its form again. Smell and taste of the baked product was evaluated via degustation.

The volume yield in [ml/100 g flour] was determined via the Chopin volumeter. At every measurement, one bread loaf or six rolls were put into the provided jar, the jar was closed and the apparatus was turned for 180° at constant speed. Then the measured volume was read from the scale. Every determination was made in duplicates. From these two values, the mean was calculated and the mean was then divided through the total amount of flour used for the baked product to get a result for 100 g of flour.

Basis for the “baking quality” was the volume yield of the baked good. The more negative attributes the baked product had during the evaluation, the more it was downgraded.

Fig. 8: Evaluation of kaiser semmel samples

12.4 BREAD AND ROLL DEGUSTATION

Bread and rolls of four different salt levels were prepared the day before in the test bakery of the VfG. The cooled baked products were put into labelled paper bags and they were stored in a dry and cool room until usage.

Bread and roll samples were encoded with random numbers, in order not to influence the assessors' judgment. Four random numbers were selected for the four bread samples and four other numbers were selected for the four roll samples (Tab. 11). Paper plates were labelled with these random numbers and the sliced bread and roll pieces were then put onto the paper plates based on their encoding. The bread and roll pieces were prepared in the kitchen of the sensory lab at the BOKU. They were cut with an electric bread slicing machine and had a thickness of about 1 cm, a length of about 6 cm and a width of about 4 cm. End pieces of the baked products were not used for the test. Test plates were prepared in small amounts only to ensure that the samples remain as fresh as possible.

The bread and roll degustation consisted of four bread and four roll samples each, which were evaluated by untrained assessors in the atrium of the BOKU with the help of a hedonic ranking test. People were invited to rank the samples, at first based on one's personal preference and the second question on the back of the test protocol was about ranking the samples due to their saltiness. The test protocol was designed this way in order to not influence the assessor's preference beforehand with the second question. The assessors were able to sit down at U-shaped tables. A glass of water was provided to them to neutralize the palate. During the evaluation, test persons were observed to avoid copying.

Tab. 11: Order and random numbers of the bread and roll degustation

sample	salt level [% mas] on flour basis	encoding	salt level [% mas] on flour basis	encoding
	mixed rye-bread		kaiser rolls	
1	1,7	929	2,5	698
2	1,5	347	1,7	309
3	2,0	796	1,5	770
4	2,5	268	2,0	285

12.5 NaCl DETERMINATION IN AUSTRIAN BREAD AND ROLLS

12.5.1 SAMPLE PREPARATION

All of the product samples were analysed in the laboratory of the VfG.

Bakers from all over Austria were invited to send a mixed rye-bread (70:30) and a kaiser roll to make a free and anonymous analysis of the salt content. For this diploma thesis, 19 bakers (i.e. two from each Austrian province) were selected to create an overview on current salt content situation in bread and rolls in Austria.

The baked goods were sent by post. They came wrapped in paper bags to avoid early moulding and they were either stored in the freezer until testing or they were tested immediately after their arrival.

Prior to the titration, the baked goods had to get dried. Therefore, two slices (for a repeat determination) were cut with a knife from the centre of the baked product to get an aliquot portion of the crust. Afterwards, the slices were cut in a way to get 10 ± 0,004 g of sample inclusively a representative portion of the crust, as seen in the draft (Fig. 9). The samples were weighed into metal cups and the number of each metal cup was noted as well to avoid confusion.

The metal cups with the samples were put into the drying oven for about 1 h at 135 ± 1 °C. Afterwards, the moisture of each sample was determined and the value was noted. The metal cups were put into the desiccator for another hour to cool down.

Each test sample duplicate was then given into the Knifetec milling apparatus, it was closed and the mill was started. After two times of 10 s of milling, the Knifetec was stopped and the ground sample was poured into a labelled plastic cup which was well sealed with a screw cap to keep the sample dry until usage (Fig. 10).

During all steps of the sample preparation gloves were used in order to avoid contamination.

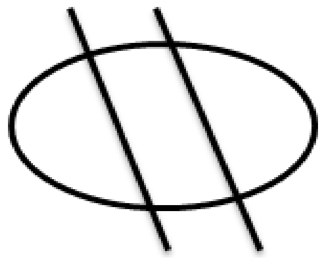

Fig. 9: Draft of a representative cut in the bread or roll slice

Fig. 10: Storage cups for the dried and ground bread and roll samples

12.5.2 ANALYSIS

At the beginning of each measuring day a blind test was made with 0,1 M NaCl-standard solution. Therefore, 5 mL of standard solution were pipetted into a 200 mL beaker with the help of a 1000 µL Eppendorf pipette in order to replace the test sample. The further procedure continued as described below. The result of this measurement was used as titer. This value was then subtracted from the titration results.

About 2 g of finely ground test sample were weighed into a weighing boat. The exact amount was marked up and the sample was transferred into a 200 mL beaker. The beaker was closed with parafilm to prevent the sample from getting moist until usage (Fig. 11). About 50 mL of ethanol absolute 99,8 % vol was measured in a 50 mL measuring cylinder and was transferred into the 200 mL beaker by letting the ethanol flow alongside the wall of the beaker to wash down all sample particles. Next, about 50 mL of aqua deion., about 5 mL of nitric acid and a magnetic stirring bar were added to the beaker.

The beaker was then put onto the magnetic stirrer of the Metrohm® titrino plus. The device was switched on, the sample was named on the display and the weighed amount of test sample was entered. The electrode and the burette were slowly moved into the solution of the beaker until a flushing of them was guaranteed. After this, the magnetic stirrer was started and the solution was stirred for 10 min; subsequently, the titration started automatically with the starting point being the turning point. The progress of the titration could be observed on the display of the titroprocessor (Fig. 12). AgCl precipitated until the end point was reached and no more free Cl^- was available. The amount of AgCl was then automatically determined by potentiometric measurement. The actual amount of salt was then calculated by using the formula from chapter 11.5.1.

Fig. 11: Beakers with bread and roll samples, sealed with parafilm

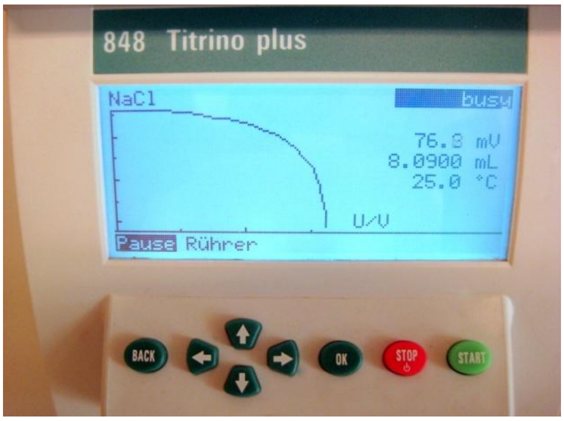

Fig. 12: Titration progress, as observed on the display of the titroprocessor

13 RESULTS AND DISCUSSION

13.1 DOUGH RHEOLOGICAL METHODS

A Pearson's r was computed via SPSS to assess the relationship between all specific values and salt level. Diagrams were made with MS Excel 2010®.

It may be of importance to mention that the results of the empirical dough rheological measurements do only refer to the flour used in the experiment (i.e. W700), whose quality was more or less in the lower standard range, as preliminary analyses showed (Tab. 3).

13.1.1 EXTENSOGRAM METHOD

Results of the extensogram titrations are listed in Tab. 12. They show a significantly negative correlation (Pearson's r = - 0,925; $p < 0{,}01$) between the two values salt level and water absorption, which means the more salt the dough contained, the less water could be absorbed by it (Fig. 13) . The biggest jump in water absorption was noted when the salt level changed from 0 % mas (60,4 % w.a.) to 1 % mas (58,9 % w.a.) with a difference of 1,5 %. Increasing salt levels from 1 % mas to 2,5 % mas did not cause as big differences in water absorption. Surprisingly, at a salt level of 2,0 % mas, water absorption slightly increased again, but this outlier was not significant. One explanation could be the nature of the flour, though.

Overall, these findings encourage speculations about the anti-swelling effect of salt in gluten made by GALAL et al. (1978). Gluten may tighten up in presence of salt, allowing less water to be absorbed by the dough. This means that there may also be less water available for other reactions – a fact which may be of interest concerning product shelf life.

Nevertheless, according to these results, a salt reduction from 2,5 % mas salt on flour basis to the sought salt level of 1,7 % mas would affect water absorption by only 0,5 %, which may be a controllable or even negligible amount, in practice.

Tab. 13 reveals mean results for extensogram measurements which were analysed and digitalised by the Brabender® software. Individual results can be found in the appendix. For further calculations, values after 135 min (red curve, s. Fig. 1) were considered only, because they generally allow the best conclusions for bakers on volume and size of their final bread and small baked goods.

Data show that energy values significantly increased (Pearson's r = 0,983; p < 0,01), the more salt was added to the flour (Fig. 14). The biggest jump (34 cm^2) was recorded when salt level changed from 0 % mas to 1 % mas. Considering current salt levels ranging from 2 % mas to 2,5 % mas (MAR, 2010), a regulation down to the required level of 1,7 % mas would cause an average change in energy reaching from 18 % to 34 % for this flour sample dependent on the initial salt concentration.

The relationship between salt level and extensibility (Fig. 15) seemed to be not as strong (Pearson's r = 0,779), a fact which was also found via confocal laser scanning with conclusions about the existence of an ideal salt level for extensibility (HEIDOLPH et al., 2011).

Resistance to extension (R, Fig. 16; Pearson's r = 0,994; p < 0,01) and maximum resistance to extension (R_{max}, Fig. 17; Pearson's r = 0,991; p < 0,01) also showed a significantly positive correlation for different salt levels. When taking a glance on salt reduction from 2 % mas or 2,5 % mas down to a level of 1,7 % mas, one could see a difference in R ranging from 13 BU to 80 BU mean value for the used flour sample, which means that 4 % to 20 % of R and 11 % to 28 % of R_{max} got lost by salt reduction to a level of 1,7 % mas.

Results in R_{max} do not support findings by LYNCH et al. (2009), who could not show a significant correlation between the two variables "salt level" and R_{max}. This may have been due to relatively high and overlapping standard deviations for measurements at each salt level during their tests.

The values R and R_{max} give a hint on how long dough is able to survive a mixing process without getting sticky due to breakage of the gluten network. In this case, resistance to over-mixing decreased, the more salt was omitted.

Ratio number (Pearson's r = 0,979, p < 0,01) and ratio number max. (Pearson's r = 0,987; p < 0,01) were also significantly affected by salt (Fig. 18). The results showed a positive correlation between ratio number or ratio number max. and salt level. In practice, these results may suggest a more stubborn dough, the more salt would be added. Therefore, during proof time, doughs with lower salt levels may be more aerated, as gas pressure inside the dough would be strong enough to stretch the dough to a greater extent.

Overall, empirical results from the extensogram measurements showed that a salt reduction could result in a reduction of fermentation stability. But the outcomes generally suggested that doughs with a salt level of 1,7 % mas would be technologically feasible and should not cause serious problems to bakers concerning their production.

During the extensogram experiments one could sense that dough became more compact the more salt was added to the flour. This was possibly due to the strengthening effect of salt on gluten (DANNO and HOSENEY, 1982; BELITZ et al., 2001; BUTOW et al., 2002). Nevertheless, the biggest difference was found between dough when salt was omitted and dough with a salt amount of 1 % mas. Dough with 0 % mas salt was very sticky and it was difficult to get it off the kneading hooks.

Tab. 12: Extensograph water absorption at various salt levels

Salt level [% mas on flour basis]	Water absorption [%]
0,0	60,4 ± 0,1
1,0	58,9 ± 0,1
1,5	58,5 ± 0,1
1,7	58,4 ± 0,2
2,0	58,7 ± 0,1
2,5	58,1 ± 0,1

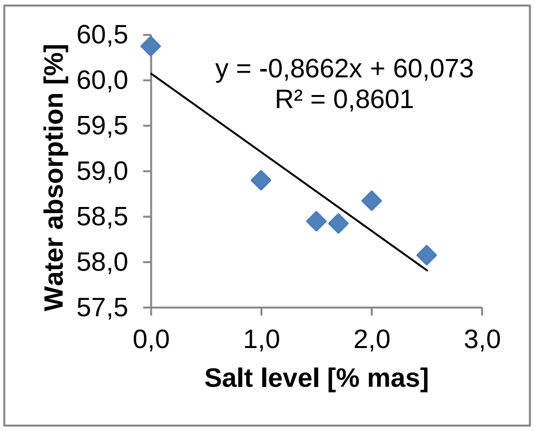

Fig. 13: Impact of various salt levels on extensogram water absorption

Tab. 13: Mean rheological extensograph data of doughs at different salt levels, shown by the red curve

Salt level [% mas on flour basis]	Energy [cm²]	Extensibility [mm]	Resistance to extension [BU]	R_{max} [BU]	Ratio Number	Ratio Number [max.]
after 135'						
0,0	30 ± 1	135 ± 5	130 ± 2	147 ± 4	1,0 ± 0,1	1,1 ± 0,1
1,0	64 ± 3	154 ± 5	229 ± 8	300 ± 8	1,5 ± 0,1	2,0 ± 0,1
1,5	71 ± 3	149 ± 3	263 ± 8	343 ± 11	1,8 ± 0,1	2,3 ± 0,1
1,7	78 ± 3	142 ± 4	310 ± 5	401 ± 9	2,2 ± 0,1	2,9 ± 0,1
2,0	95 ± 5	158 ± 3	323 ± 23	452 ± 26	2,1 ± 0,1	2,9 ± 0,2
2,5	118 ± 3	160 ± 2	390 ± 15	560 ± 26	2,5 ± 0,1	3,5 ± 0,2

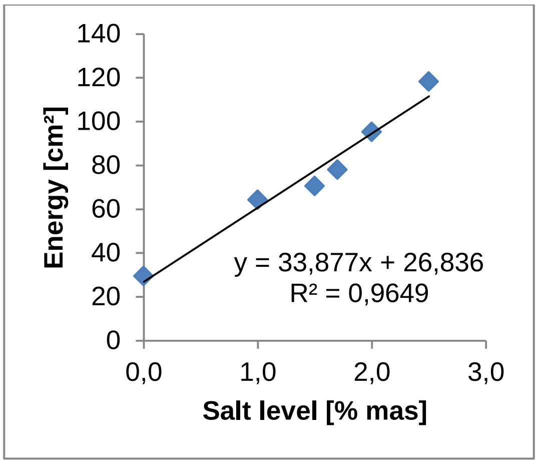

Fig. 14: Impact of various salt levels on energy

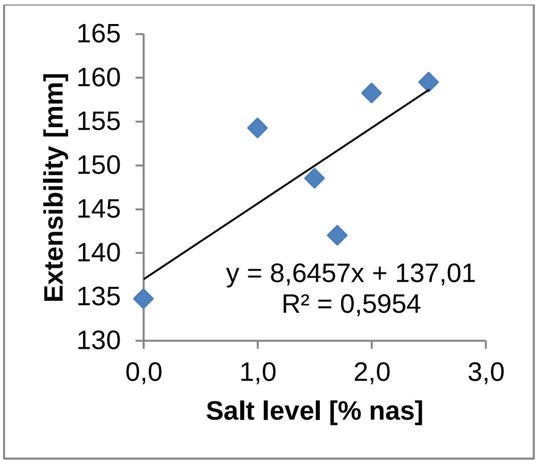

Fig. 15: Impact of various salt levels on extensibility

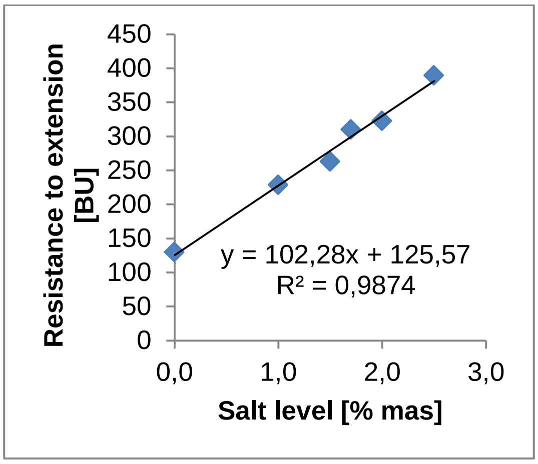

Fig. 16: Impact of various salt levels on resistance to extension

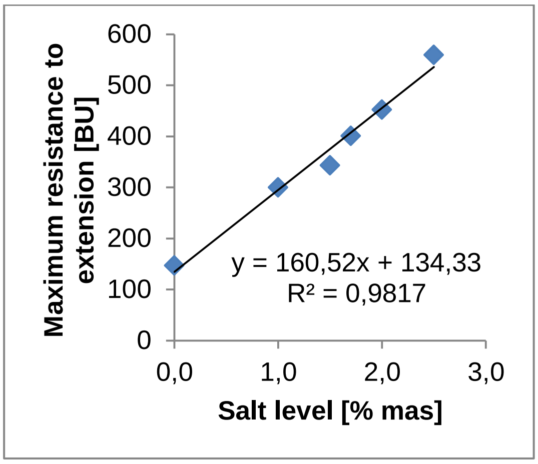

Fig. 17: Impact of various salt levels on maximum resistance to extension

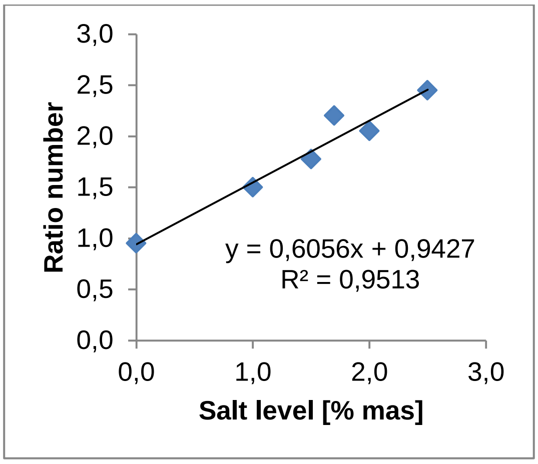

Fig. 18: Impact of various salt levels on ratio number

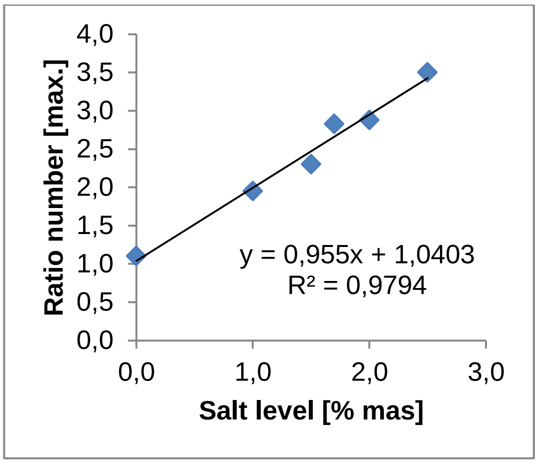

Fig. 19: Impact of various salt levels on maximum ratio number

13.1.2 FARINOGRAM METHOD

All of the measurements were made at constant consistency (500 ± 20 BU).

Water absorption was significantly affected by the amounts of salt added to the flour (Pearson's r = - 0,978; p < 0,01). These results (Tab. 14; Fig. 20) go along with findings made by HLYNKA et al. (1962). Correlation between salt level and water absorption was negative, as shown with the extensograph method. The biggest jump (0,9 %) was found at a change in salt level from 0 % mas (61,2 % w.a.) to 1 % mas (60,3 % w.a.). Water absorption was not so much affected when changing salt level from 2,5 % mas or 2 % mas to 1,7 % mas.

For the baker, a higher water absorption usually is of desire, because of the higher yield of bread which is obtained in consideration of the amount of flour used in the recipe (HOLAS and TIPPLES, 1978). But it is not possible to assess with this empirical method to what extent or even whether yield of bread would be increased at all by lower salt levels.

On the other hand, CAUVAIN (2007) suggested adding less water to salt-reduced dough in order to balance out doughs which become stickier the less salt is added to them.

Tab. 15 reveals mean results of farinogram measurements which were analysed and digitalised by the Brabender® software.

The addition of salt caused a significant increase in development time at constant consistency (Fig. 21; Pearson's r = 0,984; p < 0,01). Regardless of the big jump in development time at a change in salt level from 0 % mas to 1 % mas, each 1 % mas increase in salt would cause a mean increase in development time of about 2 min, according to these results. The outcomes are in agreement with those obtained by HLYNKA (1962) and LINKO (1984), even though their conclusion was that each 1 % mas of salt increased development time for only 0,5 min. Perhaps, these different results were due to the usage of different flours inclusively measuring fluctuations inherent in farinograph experiments.

Mean stability (Fig. 22) was also significantly increased by salt (Pearson's r = 0,964; p < 0,01). Results show that salt increases stability of dough and therefore making it less susceptible to over-mixing. In this case, a change in salt level from 2,5 % mas or 2,0 % mas to the sought level of 1,7 % mas would cause a mean decrease in stability of about 12 %.

Degree of softening 10 min after start (Fig. 23; Pearson's r = - 0,909; p < 0,05) and degree of softening ICC/12 min after max. (Fig. 24; Pearson's r = - 0,961; p < 0,01) were found to be correlated with the salt level in a negative way. The more salt was in the dough, the less fast it got soft.

Farinograph quality number (Fig. 25) and salt level showed a significantly positive correlation to each other (Pearson's r = 0,974; p < 0,01). In accordance to the results, a salt reduction from 2,5 or 2,0 % mas to the sought level of 1,7 % mas would cause a mean loss of Farinograph quality number ranging from 21 % to 29 %.

Tab. 14: Farinograph water absorption at various salt levels

Salt level [% mas on flour basis]	Water absorption [%]*
0,0	61,2 ± 0,1
1,0	60,3 ± 0,1
1,5	59,8 ± 0,0
1,7	59,7 ± 0,0
2,0	59,5 ± 0,0
2,5	59,3 ± 0,0

*(corrected to 500 BU);

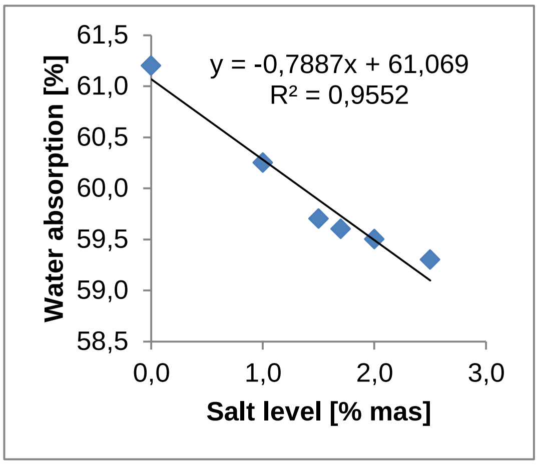

Fig. 20: Impact of various salt levels on farinogram water absorption

Tab. 15: Rheological farinograph data* of doughs with different salt levels

Salt level [% mas]	Development time [min]	Stability [min]	Degree of softening [BU]**	Degree of softening [BU]***	Farinograph quality number	Consistency [BU]
0,0	5,3 ± 0,4	12,5 ± 0,0	14,0 ± 4,2	50,5 ± 3,5	126,5 ± 3,5	488,5 ± 0,7
1,0	8,9 ± 0,4	20,3 ± 0,6	4,0 ± 1,4	39,5 ± 4,9	176,0 ± 9,9	491,0 ± 1,4
1,5	10,3 ± 0,3	26,4 ± 1,3	3,0 ± 4,2	27,0 ± 7,1	231,0 ± 9,9	492,5 ± 3,5
1,7	10,5 ± 0,6	25,3 ± 3,7	2,5 ± 1,7	33,5 ± 7,8	212,5 ± 33,2	511,0 ± 5,7
2,0	10,9 ± 0,2	28,6 ± 0,0	4,0 ± 1,4	20,0 ± 4,2	267,5 ± 2,1	512,5 ± 12,0
2,5	12,1 ± 0,6	28,6 ± 3,2	0,0 ± 0,0	12 ,0± 0,0	300,0 ± 0,0	503,0 ± 1,4

*Mean values of duplicates ± standard deviation; *(10 min after start); **(ICC/12 min after max.)

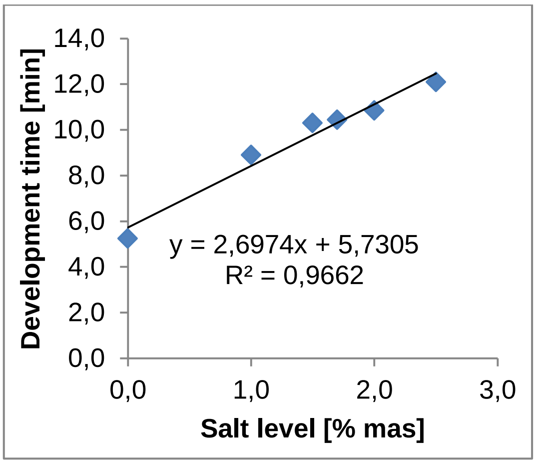

Fig. 21: **Impact of various salt levels on development time**

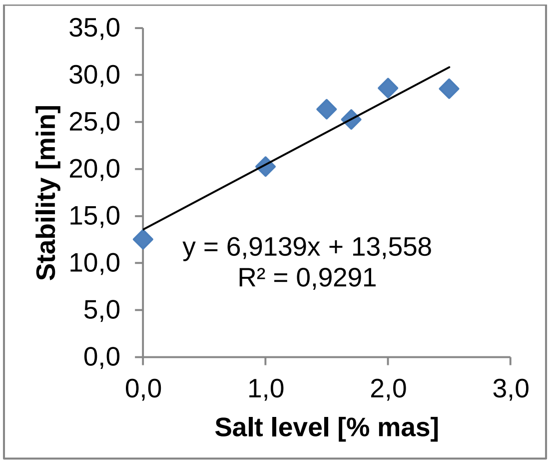

Fig. 22: **Impact of various salt levels on stability**

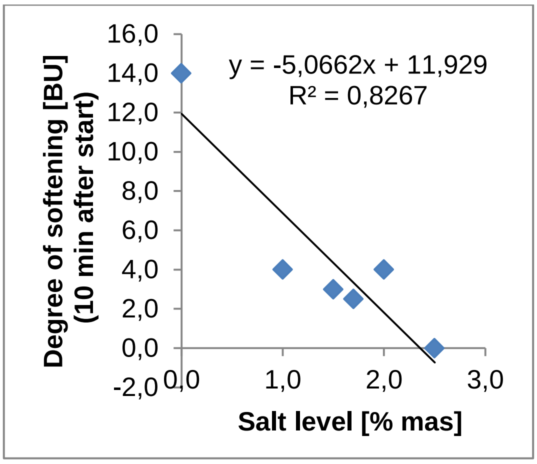

Fig. 23: **Impact of various salt levels on degree of softening (10 min after start)**

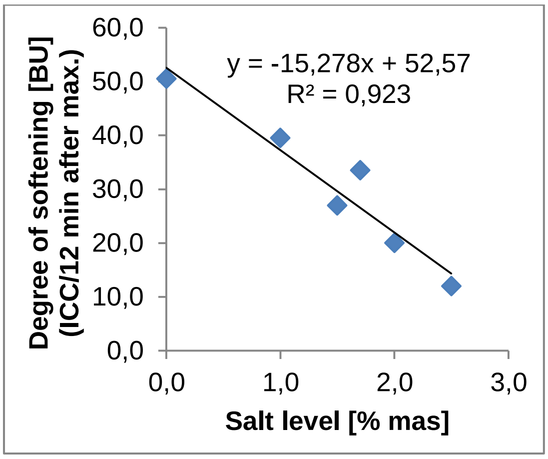

Fig. 24: **Impact of various salt levels on degree of softening (ICC/12 min after max.)**

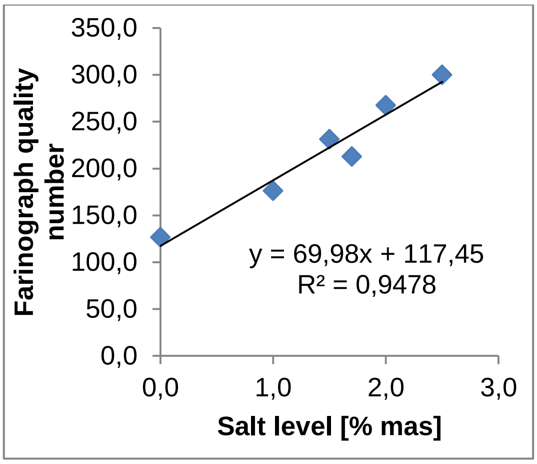

Fig. 25: **Impact of various salt levels on farinograph quality number**

13.2 BAKING TESTS

Overall, it has to be stated that foregoing empirical attempts via extensograph and farinograph measurements to define possible impacts of salt on dough forming were specifying a direction; nevertheless, it was very difficult to compare empirical with practical tests, as on the one hand, further ingredients of the baked products may also have influence on baking performance and on the other hand, there was no special analytical equipment available to detect difference in a more precise way.

13.2.1 MIXED RYE-BREAD TEST

Based on pre-determined evaluation criteria (s. 10.4; Tab. 4), every dough, respectively every bread of different salt content was evaluated and its attributes were noted down on baking protocols, which were summarised in Tab. 16.

During the processing of the doughs of various salt levels, no big differences could be found concerning their machinability. Nevertheless, dough with a salt level of 2,5 % mas felt slightly short, tight and dry and dough with a salt level of 1,5 % mas had somewhat impaired initial dough handling quality, as it was less tight and more sticky. A “runny” dough could not be observed in any of the cases.

Evaluation of the baked bread (Fig. 26) did not show any significant differences in between the four mixed rye-bread samples. There was no visible variance in crust browning. Appearance of all bread loaves was found to be normal and the crumb porosities did not show any noticeable deviations either; only at 1,5 % mas salt content the crumb structure seemed to become slightly uneven. This may be due to higher activity of the yeast cells at lower salt levels (SCHÜNEMANN and TREU, 1993).

Crumb elasticity was found to be good enough at all salt levels. Taste of bread with a salt level of 2,5 % mas was stated to be normal, up to salty and bread with a salt level of 1,5 % mas was perceived to be normal, up to slightly insipid. It should be noted, though, that the assessors were aware of the salt levels in the bread samples and therefore they were already influenced in their decision making.

A connection between mean volume yield of the bread loaves and salt level could not be found with the volumeter. Maybe salt did not have as great impacts on the volume of bread loaves, as expected. But these results may also be due to inaccuracy inherent to the test method.

KÖHLER et al. (2010) found the highest final bread loaf volume with 0,5 % mas salt addition. On the other hand, SPEIRS et al. (2009) detected a loaf rising effect of salt when they added between 0,8 % mas and 2,0 % mas salt on flour basis. They tried to explain these outcomes, besides other factors, in reference to the effect that salt has on starch gelatinization temperature (s. 3.2.2).

In the end, breads with a salt level of 2 % mas and 1,7 % mas were considered as good in baking quality, whereas bread with a salt level of 2,5 % mas was rated as satisfactory and the bread sample with the 1,5 % mas salt level was found to be poor concerning its overall baking quality.

Tab. 16: Summary of the assessed attributes of mixed rye-bread with various salt levels

	2,5 % mas NaCl	2,0 % mas NaCl	1,7 % mas NaCl	1,5 % mas NaCl
dough evaluation				
surface	slightly dry	normal	normal	normal
dough structure (elasticity)	slightly short	normal	normal	normal
processing properties of dough	good	good	good	satisfactory
bread evaluation				
form, appearance	normal	normal	normal	normal
browning	normal	normal	normal	normal
character of crust	normal	normal	normal	normal
crumb porosity, crumb structure	normal	normal	normal	normal (slightly uneven)
crumb elasticity	good	very good	good	normal
smell/taste	normal, salty	normal	normal	normal, slightly insipid
volume yield	338 = good	328 = good	334 = good	327 = good
baking quality	satisfactory	good	good	poor

Fig. 26: Mixed rye-bread of various salt levels, 1 h after baking

13.2.2 KAISER ROLL BAKING TEST

Results of the kaiser roll baking test are summarised in Tab. 17.

Dough evaluation revealed a surface drying influence of salt on doughs at salt levels of 2,0 % mas and 2,5 % mas. Doughs of other salt levels appeared moister and their dough structure was smoother, as well. These findings go along with those obtained by KLEINERT et al. (2009), who also assessed plain wheat dough for rolls in their study.

Overall processing properties were found to decrease the less salt was in the dough. The doughs of the two higher salt levels were graded as good in their machinability, whereas the two other doughs were only satisfactory, or even slightly poor (at 1,5 % mas).

Roll evaluation revealed good ratings for kaiser rolls with a salt content of 1,7 % mas and 2,0 % mas. Form, appearance, crust browning, break and shred as well as crumb porosity were within the normal limits. Crust browning of rolls at a salt level of 2,5 % mas was found to be significantly stronger than at all the other salt levels. This characteristic might lead back to the fact that yeast activity is influenced by salt and therefore more reducing sugars are left for Maillard reaction during the baking process. In contrast, kaiser rolls with a salt level of 1,5 % mas were quite pale, break and shred was rated to be only satisfactory. The roll itself appeared slightly flat at this salt level, which was then confirmed at the volume measurement, as their volume yield was slightly lower compared to rolls of other salt levels.

Nevertheless, KLEINERT et al. (2009) could not find significant differences in roll volume, although their tests were made via the more accurate laser measurement. They stated that one reason for not finding any differences during their investigations could have been the flour used in the baking tests, as it was high in gluten and therefore strong in its behaviour.

The low salt level also seemed to have influence on crumb structure and porosity, which looked slightly uneven at rolls with a salt content of 1,5 % mas. All of the other salt levels did not show any abnormalities.

Overall baking quality for rolls with a salt content of 2,0 % mas was rated to be the best, when compared to rolls of other salt levels. Baking quality for rolls with a salt level of 1,5 % mas and 2,5 % mas were only satisfactory, in the end.

Tab. 17: Summary of the assessed attributes of kaiser rolls with various salt levels

	2,5 % mas NaCl	2,0 % mas NaCl	1,7 % mas NaCl	1,5 % mas NaCl
dough evaluation				
surface	slightly moist	slightly moist	moist	moist
dough structure (elasticity)	normal	normal	smooth	smooth
processing properties of dough	good	good	satisfactory	satisfactory – poor
roll evaluation				
form, appearance	high	normal	normal	slightly flat
browning	strong	normal	normal	low
break and shred	satisfactory	good	good	satisfactory
crumb porosity	medium	medium	medium	medium – uneven
smell/taste	normal, salty	normal	normal	normal
volume yield	739 = good	757 = very good	743 = very good	712 = good
baking quality	satisfactory	very good	good	satisfactory

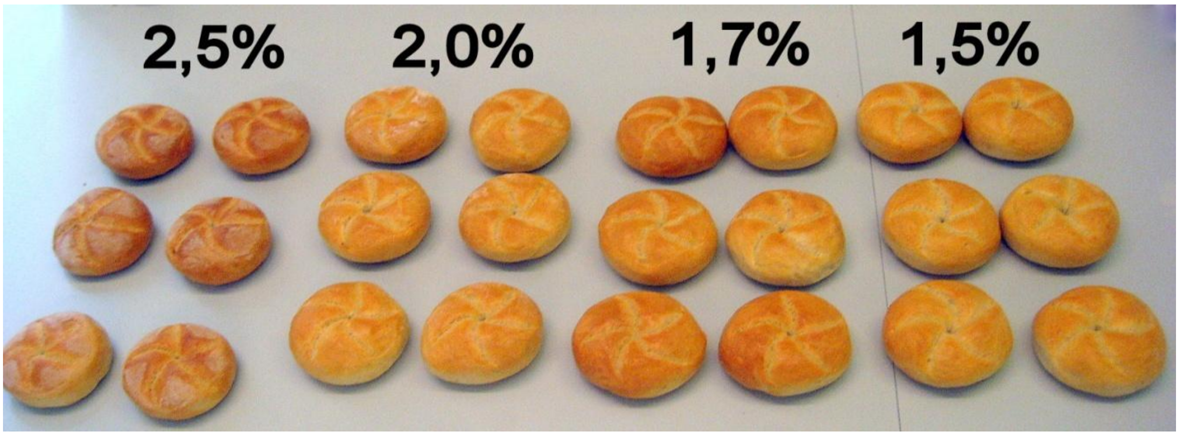

Fig. 27: Kaiser rolls of various salt levels, 1 h after baking

13.3 SENSORY EVALUATION OF BREAD AND ROLLS

13.3.1 MIXED RYE-BREAD

For the sensory evaluation of mixed rye-bread 73 consumers could be recruited that were aged between 18 and 46 years. Mean age was about 27 years and 67 % of the assessors were male.

It was found that bread samples did not differ significantly in their overall preference ($p = 0{,}758$), when evaluated via Friedman test. All of the breads were nearly equally preferred (Fig. 28). Bread containing 1,7 % mas salt on flour basis was ranked just on first place – but without significance. This result may probably give encouragement to bakers as far as 1,7 % mas is the aimed salt level of the bakers guild. The last place went to bread with a salt level of 1,5 % mas which may lead to speculations concerning salt level limits for consumer acceptance, but also for technological reason, as far as a salt level of 1,5 % mas on flour basis in bread is considered to be the lower limit to ensure product machinability without troubles (MAR, 2010).

Nevertheless, in consideration of the testing method itself, it has to be kept in mind that – in retrospect – a ranking test may have been not the best option to assess consumer acceptance, whereas scales with seven or nine scale points would have provided more information on personal liking (BUSCH-STOCKFISCH, 2011). In accordance to this fact, another interpretation of data was made via ANOVA with *Tukey* testing to confirm results, when ranks were transformed to grades and got added up, but outcomes did not change.

Results of the second question (Fig. 29) show that consumers were able to rank bread samples according to their saltiness in a highly significant way ($p = 0,000$), as evaluated via Friedman test.

Wilcoxon test and *Nemenyi's* post-hoc test, though, revealed no significant difference concerning saltiness perception between 1,5 % mas and 1,7 % mas ($p = 0,397$), between 1,5 % mas and 2,0 % mas ($p = 0,112$), as well as between 1,7 % mas and 2,0 % mas. In reference to the results from the kaiser roll degustation (13.3.2), it seemed to be harder for assessors to distinguish between salt levels in bread. This may be due to the fact that rye mixed bread is more complex in aroma and therefore more components may disguise saltiness. The 2,5 % mas salt level, though, could be significantly differentiated from all lower salt levels (Tab. 18).

From all of the 64 assessors, only 8 % were able to rank bread samples in the correct order.

As it was possible to assign the same rank position for different samples and according to the fact that many assessors were using rank division at least once, it was noted that about half of the people found it hard to distinguish between the samples.

One more point of criticism is the continuous usage of the same sample arrangement. BUSCH-STOCKFISCH (2009) stated that steady sample arrangement could influence study outcomes, as the sample which is ranked on first place, is often statistically perceived as being stronger in appearance than all of the other samples. This error could have been avoided via balanced randomized order.

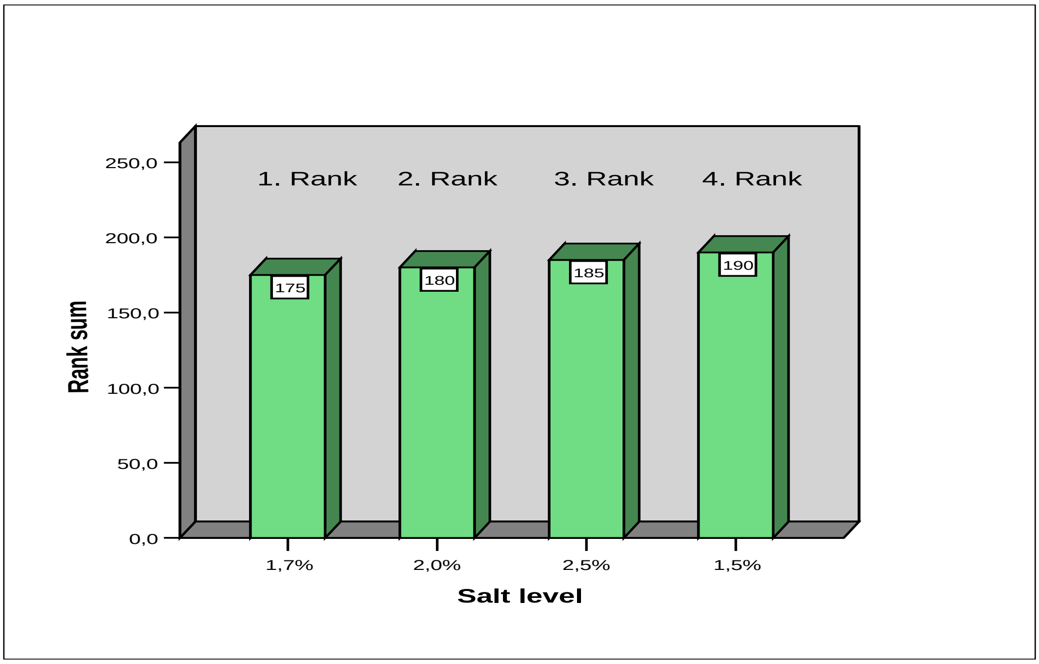

Fig. 28: Results on the mixed rye-bread ranking test according to preference

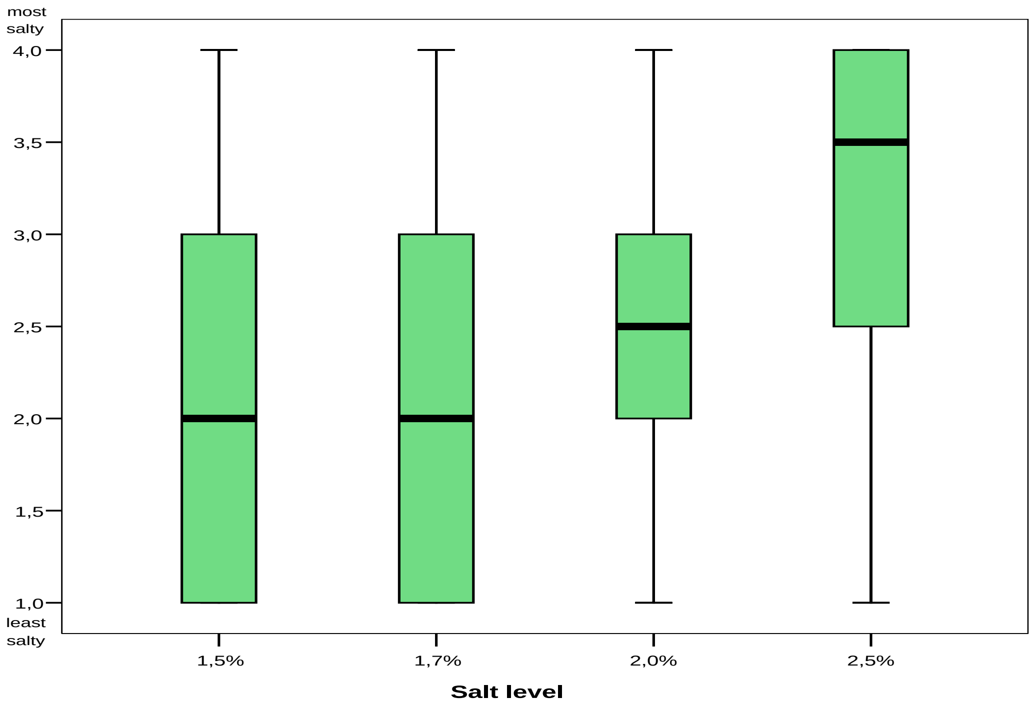

Fig. 29: Results of the saltiness ranking test for mixed rye-bread

Tab. 18: Results of Friedman post-hoc tests for saltiness ranking of mixed rye-bread

Saltiness ranking						
salt level	1,5 – 1,7 % mas	1,5 – 2,0 % mas	1,5 – 2,5 % mas	1,7 – 2,0 % mas	1,7 – 2,5 % mas	2,0 – 2,5 % mas
Wilcoxon significance	n.s.	n.s.	***	n.s.	***	***
Nemenyi's significance	n.s.	n.s.	***	n.s.	**	*

n.s. = non significant (p>0,05); * = significant (p≤0,05); ** = highly significant (p≤0,01); *** = very highly significant (p≤0,001)

13.3.2 KAISER ROLLS

The kaiser roll degustation was attended by 64 participants, the survey could therefore be regarded as being representative, according to BUSCH-STOCKFISCH (2011). Assessors were aged between 18 and 46 years with an approximate gender distribution of 67 % men and 33 % women.

When regarding the liking of kaiser rolls of various salt levels, no statistically significant difference could be detected (p = 0,572); this means that in the overall perception no roll of a certain salt level was statistically favoured, since all roll samples had about the same rank sums (Fig. 30). These outcomes reflect the same results as compared to the mixed rye-bread degustation and go along with findings from KLEINERT et al. (2009), who suggest salt reduction being a capable mission, as not even tendencies could be found on salt preference, although the highest salt level was ranked on first place.

But when the assessors were asked to rank samples on the basis of saltiness, it was shown that they were able to make significant distinctions (p = 0,000), when decidedly being asked for saltiness ranking (Fig. 31). On closer inspection via *Nemenyi's* post-hoc and *Wilcoxon* test, it was shown that no significant difference could be found by assessors between the salt levels 1,5 % mas and 1,7 % mas (p = 0,512), 1,7 % mas and 2,0 % mas and between 2,0 % mas and 2,5 % mas. All of the other salt levels could get statistically distinguished from each other (Tab. 19). These results may enhance findings of about minimum detectable differences of salt in bread starting from 0,3 % mas dependent on the control bread used for comparison (HEIDOLPH et al., 2011).

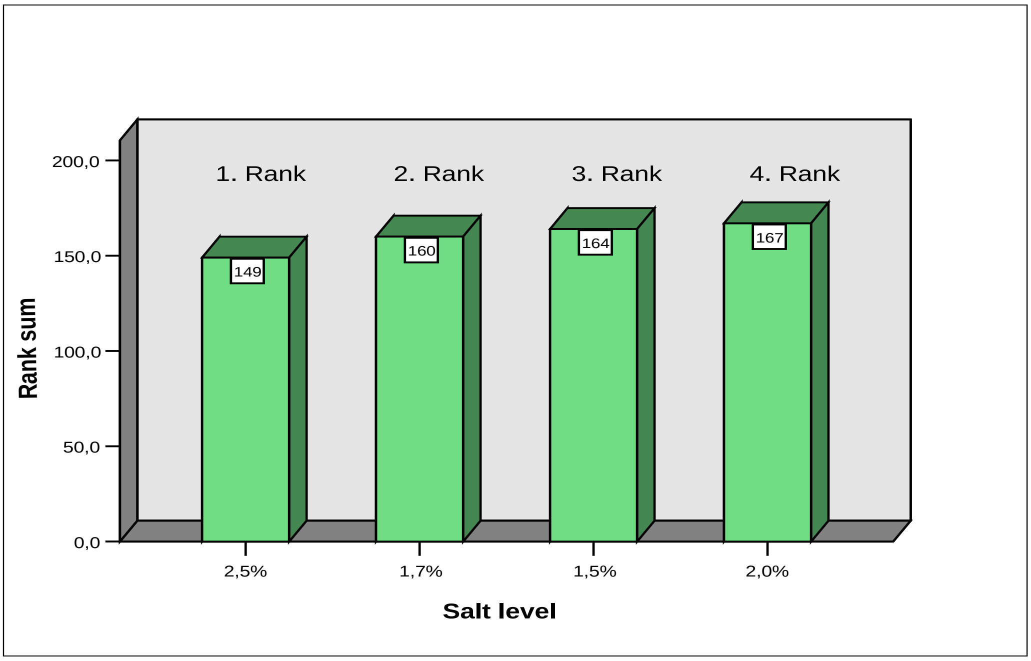

Fig. 30: Results of the kaiser roll ranking test according to preference

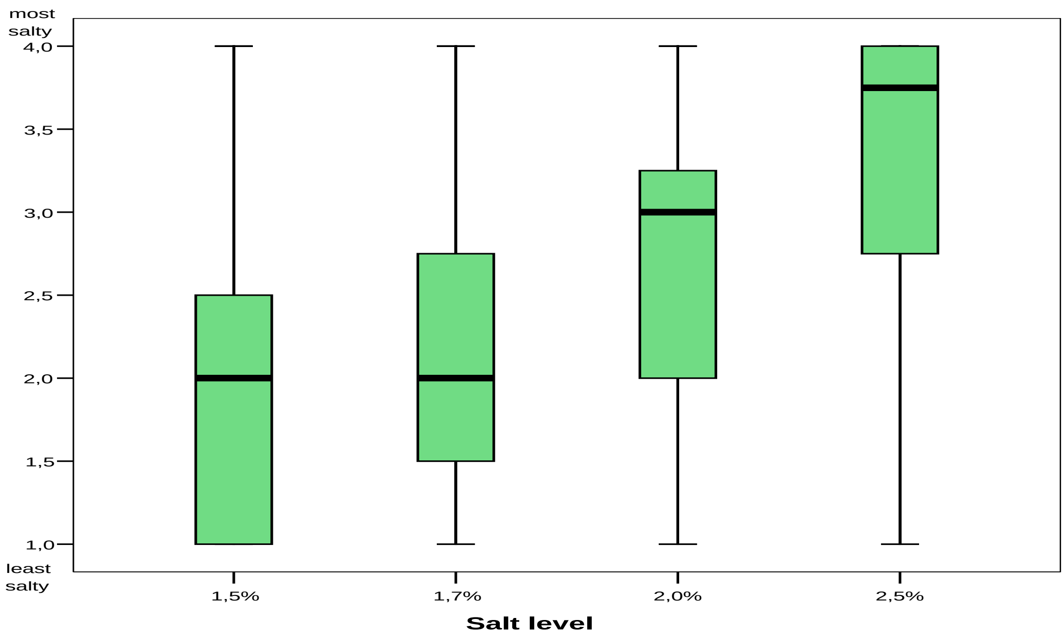

Fig. 31: Results of the saltiness ranking test for kaiser rolls

Tab. 19: Results of Friedman post-hoc tests for saltiness ranking of kaiser rolls

	Saltiness ranking					
salt level	1,5 – 1,7 % mas	1,5 – 2,0 % mas	1,5 – 2,5 % mas	1,7 – 2,0 % mas	1,7 – 2,5 % mas	2,0 – 2,5 % mas
Wilcoxon significance	n.s.	**	***	**	***	**
Nemenyi's significance	n.s.	**	***	n.s.	***	n.s.

n.s. = non significant (p>0,05); * = significant (p≤0,05); ** = highly significant (p≤0,01); *** = very highly significant (p≤0,001)

13.4 ANALYSIS OF CURRENT SALT CONTENT IN AUSTRIAN BREAD AND ROLLS

It was ensured that the bread and roll samples came from all over Austria. Altogether, salt levels of 19 mixed rye-bread samples and 19 kaiser roll samples were checked. A gradient in salt addition based on classification between Eastern (i.e. Nö, W, B), Western (i.e. Oö, T, V, S) and Southern Austria (i.e. K, St) could not be observed, the sample size may have also been too small to allow conclusions.

The fact, that staling of the baked product samples was less or more in progress (possibly due to a longer duration of transport, etc.) when the products arrived in the laboratory, led to the circumstance that moisture contents differed a lot from each other (in comparison: 4,60 % moisture for one roll sample and up to 31,3 % moisture for another roll sample). Therefore, standard moisture content for fresh products was determined to ensure better comparability in between the samples. This standard moisture was fixed at 30 % for small baked goods and 40 % for mixed rye-bread.

In order to ensure accurate conclusions on the added amount of salt per 100 g of flour it is inevitable to know about the exact percentage of flour used at the product recipe. The percentage of flour in bread and small baked goods usually is between 60 and 70 % on the basis of all ingredients. For this purpose, both values were used for further calculations.

Tab. 21 gives a short overview on the results of the salt content analysis in mixed rye bread (ratio 70:30) and in kaiser rolls. Mean salt level for mixed rye-bread amounts to 1,45 ± 0,21 % mas per 100 g of bread at 40 % standard moisture. Tested kaiser roll samples had a mean salt content of 1,50 ± 0,14 % mas per 100 g of roll at 30 % standard moisture.

Mixed rye-bread of only one single baker was already in the range of the recommended 0,9 to 1,2 % mas salt content based on 100 g of product at standard moisture. This was also the lowest salt content from all of the analysed samples. The highest salt level was found with 1,98 % mas per 100 g of bread at standard moisture. Calculated with a flour content of 70 % mas, this would have been 2,83 % mas of salt on flour basis being added to the dough, respectively 3,30 % mas at a flour content of 60 % mas. In Austria, mean bread consumption amounts to about 120 g per day (ELMADFA et al., 2008). In reference to this value, about 2,38 g of salt intake (= 950 mg Na) would derive from bread, i.e. 40 % of recommended upper limit for daily salt intake. At recommended bread intake of at least 240 g per day, this would be 4,76 g (= 1900 mg Na) or 80 % of recommended daily upper limit for salt intake with only about 1,2 g of salt left for other salt sources.

When calculating with a flour content of 60 % mas, then only one mixed rye-bread sample would already have a salt level under 2,0 % mas on flour basis, but none of the kaiser rolls. Mean salt level would then be at about 2,41 % mas on flour basis for mixed rye-bread and 2,50 % mas for kaiser rolls. On the other hand, when calculating with a flour content of 70 % mas, then ten bread samples or six kaiser roll samples would already have a salt content of less than 2,0 % mas on flour basis. Mean salt addition would range at about 2,06 % mas for mixed rye-bread and 2,14 % mas for kaiser rolls.

In general, there were bigger variations in the salt content of bread samples than of roll samples.

Again, it has to be kept in mind that it is sodium which is the element of concern and not the whole salt. As described in chapter 5, sodium does not derive from salt only. Thus, more than the calculated amount of sodium from salt may be found in the baked product. But as the method of choice for this work was based on a determination of chloride content and therefore calculation of NaCl, no free or other chemical compounds could be assessed by it.

Salt reduction is already under discussion in Austria (Tab. 20), but this short overview on current salt addition in Austrian bread and rolls indicates that still a lot has to be done in order to meet recommended salt levels.

Various possibilities on the interpretation of the testing results may show how difficult it is to calculate the appropriate amount of salt that fits to the reference values – not only just for bakers. Concerning the monitoring of salt content in baked goods, there may be two options under discussion for a better comparison in between the products. One option would be a settlement on standard moistures for different categories of baked products – as described before. The other option would be a determination of salt content based on salt level in the oven dried mass. KLEINERT et al. (2009) tried to solve the problem of back-calculating from the salt content on flour basis to the salt content in 100 g of baked product by the establishment of a standard series of salt content in a variety of breads with a known concentration of salt on flour basis and subsequent potentiometric titration of these breads. The conversion factor thus obtained served KLEINERT et al. for further calculations.

Tab. 20: Overview on Austrian guidelines concerning salt reduction (according to MAR, 2010)

	Status quo	Target
salt on flour basis	2,0 – 2,5 % mas	1,7 % mas
salt /100 g baked product	1,2 – 1,8 % mas*	0,9 – 1,2 % mas*
sodium /100 g baked product	500 – 700 mg*	340 – 480 mg*
sodium /120 g baked product (current intake)	600 – 840 mg*	408 – 576 mg*

*depending on the amount of flour used for the product (50 – 70 % mas)

Tab. 21: Current salt addition in Austrian mixed rye-bread and kaiser rolls

Austrian province	NaCl [% mas] per 100 g of product at standard moisture*	Estimated NaCl [% mas] on flour basis (60 % mas flour content)	Estimated NaCl [% mas] on flour basis (70 % mas flour content)	NaCl [% mas] per 100 g of product at standard moisture*	Estimated NaCl [% mas] on flour basis (60 % mas flour content)	Estimated NaCl [% mas] on flour basis (70 % mas flour content)
	Mixed rye-bread			Kaiser rolls		
Nö	1,33	2,21	1,89	1,65	2,74	2,35
Nö	1,42	2,36	2,02	1,45	2,41	2,07
Nö	1,21	2,01	1,72	1,50	2,50	2,15
W	1,51	2,52	2,16	1,64	2,73	2,34
W	1,42	2,37	2,03	1,48	2,47	2,12
B	1,77	2,95	2,53	1,87	3,11	2,67
Oö	1,31	2,18	1,86	1,34	2,23	1,92
Oö	1,35	2,25	1,92	1,37	2,29	1,96
Oö	1,40	2,33	1,99	1,32	2,21	1,89
T	1,41	2,35	2,01	1,52	2,53	2,17
T	1,15	1,92	1,65	1,62	2,70	2,31
V	1,36	2,27	1,95	1,58	2,63	2,26
V	1,36	2,27	1,95	1,48	2,46	2,11
S	1,98	3,30	2,82	1,45	2,42	2,07
S	1,82	3,03	2,60	1,62	2,71	2,32
St	1,33	2,22	1,90	1,39	2,31	1,98
St	1,53	2,55	2,18	1,36	2,26	1,94
K	1,37	2,28	1,95	1,50	2,50	2,14
K	1,43	2,39	2,05	1,35	2,26	1,94
mean	1,45	2,41	2,06	1,50	2,50	2,14
sd	0,21	0,34	0,29	0,14	0,23	0,20
cv [%]	14,21	14,24	14,28	9,21	9,20	9,22

*standard moisture settled at 40 % for mixed rye-bread and 30 % for kaiser rolls;

14 CONCLUSIONS

Dough rheological investigations, based on tests with farinograph and extensograph revealed a correlation between salt level and empirical parameters.

Salt was found to play an important role in dough processing.

It turned out that even the slightest differences in the amount of salt added can have effects on the analysis results. One can recognize the effects of salt reduction on the analysis results - the values of meaningful parameters worsened, the lower the amount of salt was - but these facts can provide no meaningful conclusions about possible effects on overall baking characteristics in practice, as empirical methods are always made under controlled and standardised circumstances, whereas practical implementation is not. This type of analysis should specify only a direction. However, it should also be added that the results of these investigations may only match to the flour used for the analysis. In this regard, it would be interesting to do further analysis with flours of different qualities and other flour types than just W 700 used for these investigations. On the other hand, impacts of salt were observed on flour only, but dough for baking also contains other ingredients like yeast or sourdough which may be more affected than the flour itself and should therefore be kept in mind.

Baking tests with mixed rye-bread and kaiser rolls of various salt levels (1,5 % mas, 1,7 % mas, 2,0 % mas 2,5 % mas on flour basis) were performed in order to evaluate pratical impacts of salt on baked goods.

The baking test for rye bread showed that salt reduction down to a level of 1,7 % mas on flour basis may be possible without large fluctuations to expect concerning the product quality. With a salt level of 1,5 % mas however, it turned out that the crumb porosity became a little bit uneven.

With kaiser rolls one could see the effects of salt reduction more easily. The less salt was in the rolls, the lower was the crust colour. Rolls with a salt content of 1,5 % mas were rather flat in their appearance, the break and shred was satisfactory and had been a bit too bright. In addition, the pore structure seemed to be affected with irregularities, too. Processing properties of the dough could only reach a satisfactory or rather poor level. A salt reduction from 2,0 % mas to the sought level of 1,7 % mas, however, may not cause too much trouble, according to this baking test. The reduction of higher salt levels like 2,5 % mas to the desired level of 1,7 % mas may lead to noticeable changes, though. The overall baking quality of kaiser rolls with a salt content of 1,5 % mas however, was found to be only satisfactory, as impacts of salt on dough were already sizable.

Altogether, difficulties in regard of the production of salt-reduced baked products like dough stickiness or reduced mixing time should be brought under control with small adjustments concerning the manufacturing process or also ingredients to get qualitatively equivalent results.

Baking tests were followed by a degustation of the baked goods by untrained consumers at the BOKU the following day. Based on a ranking test, test persons were asked on the one hand to rank samples according to their personal preference and on the other hand they were asked to rank products due to their salt content. The results showed that there was no significant preference of any particular salt level, since the rank sum of all samples were approximately equal. This suggests that in general there are no outstanding preferences.

However, significant differences could be observed in the ranking due to saltiness. The assessors were therefore able to find significant differences in saltiness - with both kaiser roll and mixed rye-bread samples. Above all, the saltiest product could be identified quite often. According to these results, it seemed to be much harder to distinguish between salt levels that were closer to each other. This suggests that for example a reduction from 2,0 % mas to 1,7 % mas may not be perceived by many consumers, in general.

A random analysis of current salt content in Austrian bread and rolls showed that most bakers have not yet reached the target level of 1,7 % mas salt in baked goods. According to these results, many bakers still use 2,0 % mas to 2,5 % mas salt on flour basis in their products. Only one baker was with his rye bread already in the field of reference.

Through the analysis it became apparent how difficult it is - if only for bakers – to estimate the required salt concentration in relation to 100 g of freshly baked good. This is partly due to the different moisture contents in the products at the time of analysis and on the other hand the flour percentage of the recipe must be known to give advices on possible salt addition on flour basis.

15 SUMMARY

The aim of this thesis was to capture the effects of salt (NaCl) on bread and small baked goods. On the one hand, this happened from the sensory point of view on basis of a degustation of mixed rye-bread and kaiser rolls of different salt levels (i.e. 1,5 % mas, 1,7 % mas, 2,0 % mas and 2,5 % mas on flour basis) with the questions on personal preference and on classification of the samples based on their salt content. The results revealed no significant preference of a certain salt content in baked products. The question of ranking samples based on their salt content, however, showed that consumers could distinguish between baked products of different salt levels; in particular the sample with the highest salt content could be distinguished from the others most of the time. Smaller differences, e.g. between 1,7 % mas and 2,0 % mas often could not be detected.

On the other hand it was tried to determine technological impact of salt reduction on bread and pastries. In the run up to the actual baking trials it was tested by using empirical methods to determine whether any effects of salt on various dough rheological parameters can be observed. The results of extensogram and farinogram investigations and showed that even small amounts of salt can affect dough behaviour; as there were more or less high correlations between measured values and the salt concentration.

Baking tests for mixed rye-bread and kaiser rolls of different salt levels could not reveal any great – sensory evaluable – differences. Only at the kaiser rolls one could see differences in crust colour, dough consistency and overall baking quality, depending on the salt level.

In order to get a rough overview of the current salt content in bread and small baked goods, a total of 38 mixed rye-bread and kaiser rolls from 19 Austrian bakeries checked, with the result that much remains to be done to reach the recommended salt level of 0,9 % mas to 1,2 % mas based on 100 g of baked good; only one baker was already in this area with his bread. The majority seems to continue using normal amounts of salt with means between 1,43 g to 1,47 g salt per 100 g of baked product.

16 ZUSAMMENFASSUNG

Ziel dieser Diplomarbeit war es, die Auswirkungen von Salz (NaCl) auf Brot und Gebäck zu erfassen. Zum einen geschah dies aus dem sensorischen Blickwinkel anhand einer Verkostung von Roggenmischbrot und Kaisersemmeln unterschiedlicher Salzgehalte (i.e. 1,5 % mas; 1,7 % mas; 2,0 % mas und 2,5 % mas bezogen auf den Mehlanteil) mit den Fragen nach der persönlichen Präferenz und nach einer Einordnung der Proben aufgrund ihres Salzgehaltes. Dabei zeigte sich, dass es bei den Konsumenten zu keiner signifikanten Präferenz eines bestimmten Salzgehaltes kam. Die Frage nach der Reihung der Backwaren aufgrund ihrer Salzigkeit wies jedoch sehr wohl eine Signifikanz auf, hier konnte vor allem jeweils die Probe mit dem höchsten Salzgehalt von den anderen unterschieden werden. Geringere Unterschiede, wie z.B. zwischen 1,7 % mas und 2,0 % mas konnten oft nicht erkannt werden.

Andererseits wurde versucht, technologische Auswirkungen einer Salzreduktion auf Brot und Gebäck festzustellen. Im Vorfeld zu den eigentlichen Backversuchen wurde mit Hilfe von empirischen Methoden getestet, ob etwaige Auswirkungen von Salz auf verschiedene teigrheologische Parameter festzustellen sind. Die Ergebnisse der Extensogramm- und Farinogrammuntersuchungen zeigten, dass sich auch schon geringe Salzmengen auf das Teigverhalten auswirken können, es bestand also eine mehr oder weniger hohe Korrelation zwischen den einzelnen Messwerten und der Salzkonzentration.

Bei den Backversuchen konnten zwischen den einzelnen Backwaren (Roggenmischbrot mit einem Verhältnis von 70:30 und Kaisersemmeln) verschiedener Salzgehalte keine großen – sensorisch evaluierbaren – Unterschiede erkannt werden. Allein bei den Kaisersemmeln konnte man den Salzgehalt schon anhand der Krustenfärbung erkennen; auch zeigten sich Auswirkungen auf die Teigbeschaffenheit und die Gesamt-Backqualität.

Um einen groben Überblick über den derzeitigen Salzgehalt in Brot und Gebäck zu erhalten, wurden stichprobenartig insgesamt 38 Roggenmischbrot- und Kaisersemmelproben aus 19 österreichischen Bäckereien überprüft, mit dem Resultat, dass noch viel getan werden muss, um den angepeilten Salzgehalt von 0,9 bis 1,2 % mas auf 100 g Backware, zu erreichen: Nur ein Bäcker lag mit seinem Brot bereits in diesem Bereich. Der Großteil verwendet noch die weiterhin üblichen Salzmengen, im Mittel sind das 1,43 bis 1,47 g Salz auf 100 g Backware.

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18 APPENDIX

18.1 EXTENSOGRAM DATA AND GRAPHS

Tab. 22: Extensogram data after 135 min for various salt levels

Salt level [% mas on flour basis]	**Energy [cm^2]**	**mv**	**sd**	**cv [%]**	**Resistance to extension [BU]**	**mv**	**sd**	**cv [%]**	**Extensibility [mm]**	**mv**	**sd**	**cv [%]**
0,0	31 29 28 30	**30**	1	4,4	128 129 132 130	**130**	2	1,3	139 135 128 137	**135**	5	3,6
1,0	62 69 62 64	**64**	3	5,1	223 224 241 226	**229**	8	3,7	153 161 148 155	**154**	5	3,5
1,5	74 68 69 71	**71**	3	3,8	274 260 254 264	**263**	8	3,2	149 144 151 150	**149**	3	2,1
1,7	76 75 81 80	**78**	3	3,8	303 312 310 314	**310**	5	1,5	142 136 146 144	**142**	4	3,0
2,0	99 99 89 94	**95**	5	5,0	334 349 300 308	**323**	23	7,0	160 155 157 161	**158**	3	1,7
2,5	122 119 116 116	**118**	3	2,4	400 404 374 380	**390**	15	3,8	159 157 161 161	**160**	2	1,2

Salt level [% mas on flour basis]	**Maximum [BU]**	**mv**	**sd**	**cv [%]**	**Ratio Number**	**mv**	**sd**	**cv [%]**	**Ratio Number [max.]**	**mv**	**sd**	**cv [%]**
0,0	147 142 152 146	**147**	4	2,8	0,9 1,0 1,0 0,9	**1,0**	0,1	6,1	1,1 1,0 1,2 1,1	**1,1**	0,1	7,4
1,0	294 309 304 292	**300**	8	2,7	1,5 1,4 1,6 1,5	**1,5**	0,1	5,4	1,9 1,9 2,1 1,9	**2,0**	0,1	5,1
1,5	358 346 333 336	**343**	11	3,3	1,8 1,8 1,7 1,8	**1,8**	0,1	2,8	2,4 2,4 2,2 2,2	**2,3**	0,1	5,0
1,7	388 406 403 407	**401**	9	2,2	2,2 2,3 2,1 2,2	**2,2**	0,1	3,7	2,7 3,0 2,8 2,8	**2,8**	0,1	4,5
2,0	460 484 425 440	**452**	26	5,7	2,1 2,3 1,9 1,9	**2,1**	0,2	9,3	2,9 3,2 2,7 2,7	**2,9**	0,2	8,2
2,5	586 570 548 534	**560**	23	4,1	2,5 2,6 2,3 2,4	**2,5**	0,1	5,3	3,7 3,6 3,4 3,3	**3,5**	0,2	5,2

Salt level [% mas on flour basis]	Water absorption [%]	mv	sd	cv [%]
0,0	60,3 60,4 60,4 60,4	60,4	0,1	0,1
1,0	58,8 58,9 58,9 59,0	58,9	0,1	0,1
1,5	58,4 58,5 58,5 58,4	58,5	0,1	0,1
1,7	58,2 58,4 58,5 58,6	58,4	0,2	0,3
2,0	58,6 58,7 58,7 58,7	58,7	0,1	0,1
2,5	58,0 58,1 58,1 58,1	58,1	0,1	0,1

Tab. 23: Extensogram data correlation on SPSS

		salt level
water absorption	Pearson Correlation	-,925**
	Sig. (2-tailed)	,008
	N	6
energy [cm²]	Pearson Correlation	,983**
	Sig. (2-tailed)	,000
	N	6
resistance to extension [BU]	Pearson Correlation	,994**
	Sig. (2-tailed)	,000
	N	6
extensibility [mm]	Pearson Correlation	,779
	Sig. (2-tailed)	,068
	N	6
Maximum [BU]	Pearson Correlation	,991**
	Sig. (2-tailed)	,000
	N	6
ratio number	Pearson Correlation	,979**
	Sig. (2-tailed)	,001
	N	6
ratio numbermax	Pearson Correlation	,987**
	Sig. (2-tailed)	,000
	N	6

**. Correlation is significant at the 0.01 level

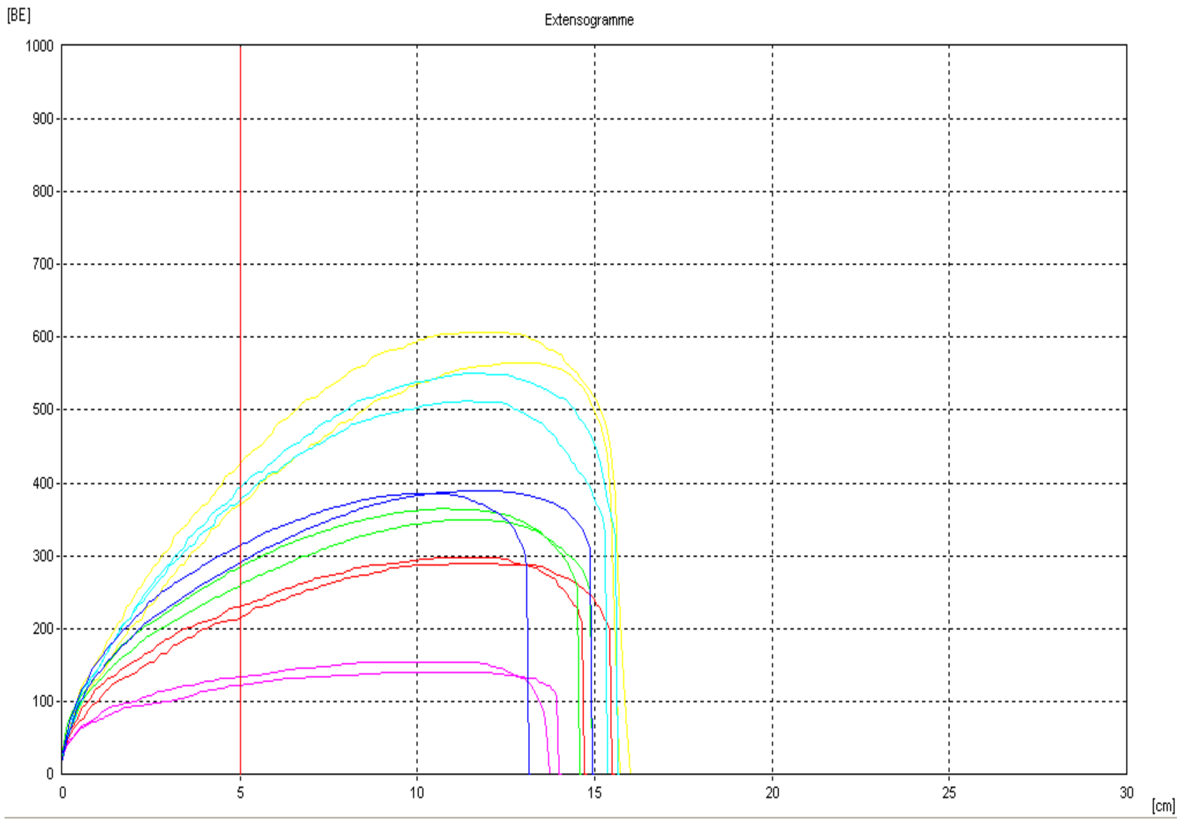

Fig 32: Correlated extensogram data at salt levels ranging from 0 % mas to 2,5 % mas after 135 min;

Pink: with 0 % mas salt on flour basis
Red: with 1,0 % mas salt on flour basis
Green: with 1,5 % mas salt on flour basis
Blue: with 1,7 % mas salt on flour basis
Turquoise: with 2,0 % mas salt on flour basis
Yellow: with 2,5 % mas salt on flour basis

18.2 FARINOGRAM DATA AND GRAPHS

Tab. 24: Farinogram data for various salt levels

Salt level [% mas] on flour basis	Develop-ment time [min]	mv	sd	cv [%]	Stability [min]	mv	sd	cv [%]	Degree of softening [BU] (10 min after start)	mv	sd	cv [%]
0,0	5,0 5,5	5,3	0,4	6,7	12,5 12,5	12,5	0,0	0,0	17 11	14,0	4,2	30,3
1,0	8,6 9,2	8,9	0,4	4,8	20,7 19,8	20,3	0,6	3,1	5 3	4,0	1,4	35,4
1,5	10,1 10,5	10,3	0,3	2,7	27,3 25,4	26,4	1,3	5,1	0 6	3,0	4,2	141,4
1,7	10,9 10	10,5	0,6	6,1	27,9 22,6	25,3	3,7	14,8	3 2	2,5	0,7	28,3
2,0	10,7 11,0	10,9	0,2	2,0	28,6 28,6	28,6	0,0	0,0	3 5	4,0	1,4	35,4
2,5	12,5	12,1	0,6	4,7	28,7	28,6	0,2	0,7	0	0,0	0,0	0,0

	11,7				28,4				0			

Salt level [% mas] on flour basis	**Degree of softening [BU] (ICC/12 min after Max.)**	**mv**	**sd**	**cv [%]**	**Farino-graph quality number**	**mv**	**sd**	**cv [%]**	**Water ab-sorption [%] (corrected to 500 BU)**	**mv**	**sd**	**cv [%]**
0,0	48 53	50,5	3,5	7,0	124 129	126,5	3,5	2,8	61,3 61,1	61,2	0,1	0,2
1,0	36 43	39,5	4,9	12,5	183 169	176,0	9,9	5,6	60,3 60,2	60,3	0,1	0,1
1,5	22 32	27,0	7,1	26,2	238 224	231,0	9,9	4,3	59,7 59,7	59,7	0,0	0,0
1,7	28 39	33,5	7,8	23,2	236 189	212,5	33,2	15,6	59,6 59,6	59,6	0,0	0,0
2,0	17 23	20,0	4,2	21,2	269 266	267,5	2,1	0,8	59,5 59,5	59,5	0,0	0,0
2,5	12 12	12,0	0,0	0,0	300 300	300,0	0,0	0,0	59,3 59,3	59,3	0,0	0,0

Tab. 25: Farinogram data correlation on SPSS

		salt level [%]
water absorption [%]	Pearson Correlation	-,978**
	Sig. (2-tailed)	,001
	N	6
development time [min]	Pearson Correlation	,984**
	Sig. (2-tailed)	,000
	N	6
stability [min]	Pearson Correlation	,964**
	Sig. (2-tailed)	,002
	N	6
degree of softening [BU] 10 min after start	Pearson Correlation	-,909*
	Sig. (2-tailed)	,012
	N	6
degree of softening [BU] (ICC/12 min after max.)	Pearson Correlation	-,961**
	Sig. (2-tailed)	,002
	N	6
Farinograph quality number	Pearson Correlation	,974**
	Sig. (2-tailed)	,001
	N	6
Consistency [BU]	Pearson Correlation	,723
	Sig. (2-tailed)	,104
	N	6

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

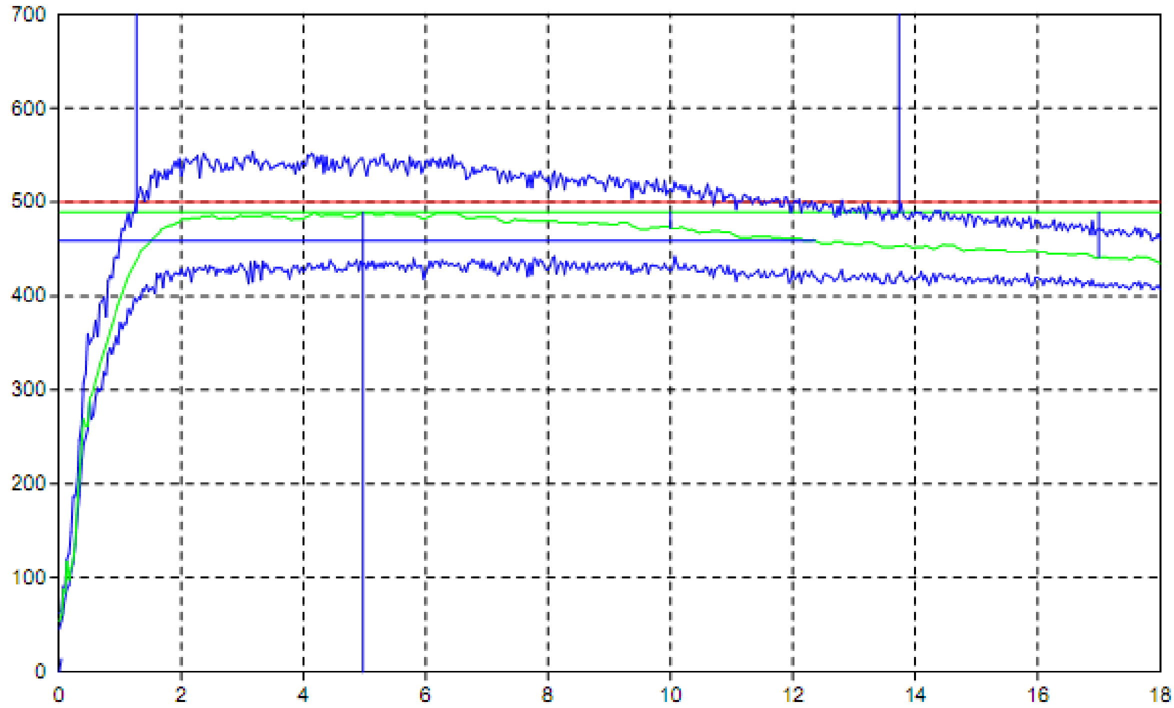

Fig. 33: Farinogram at 0 % mas salt addition

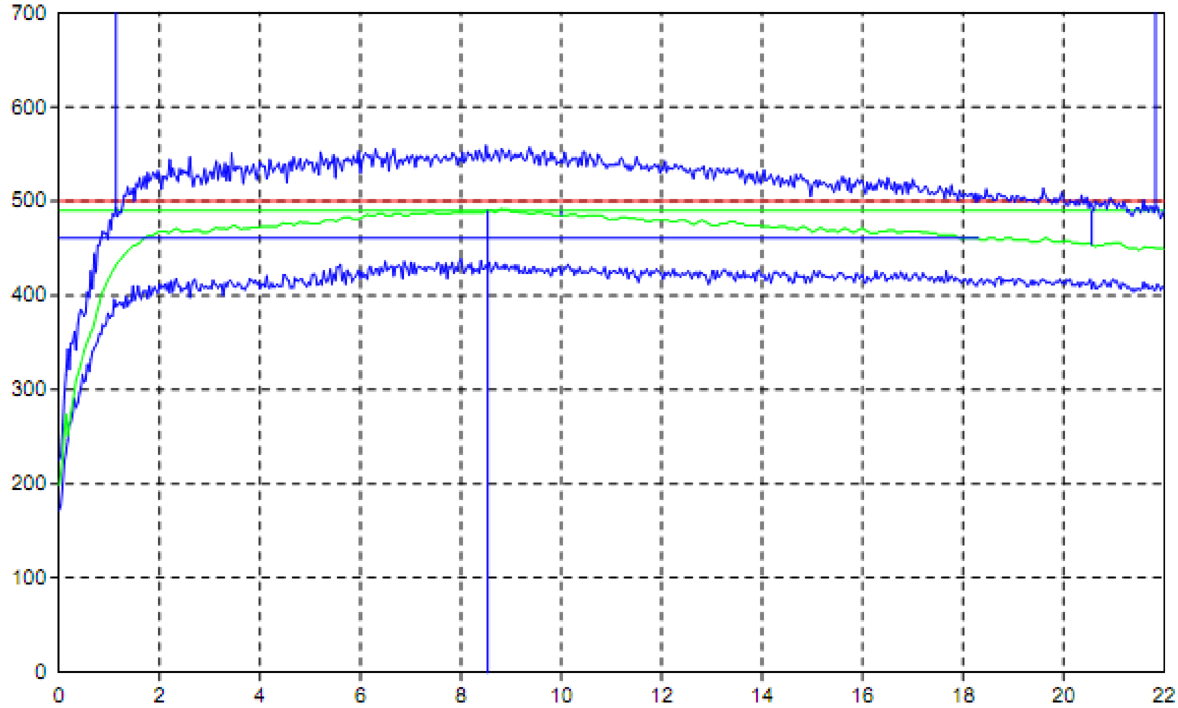

Fig. 34: Farinogram at 1 % mas salt addition

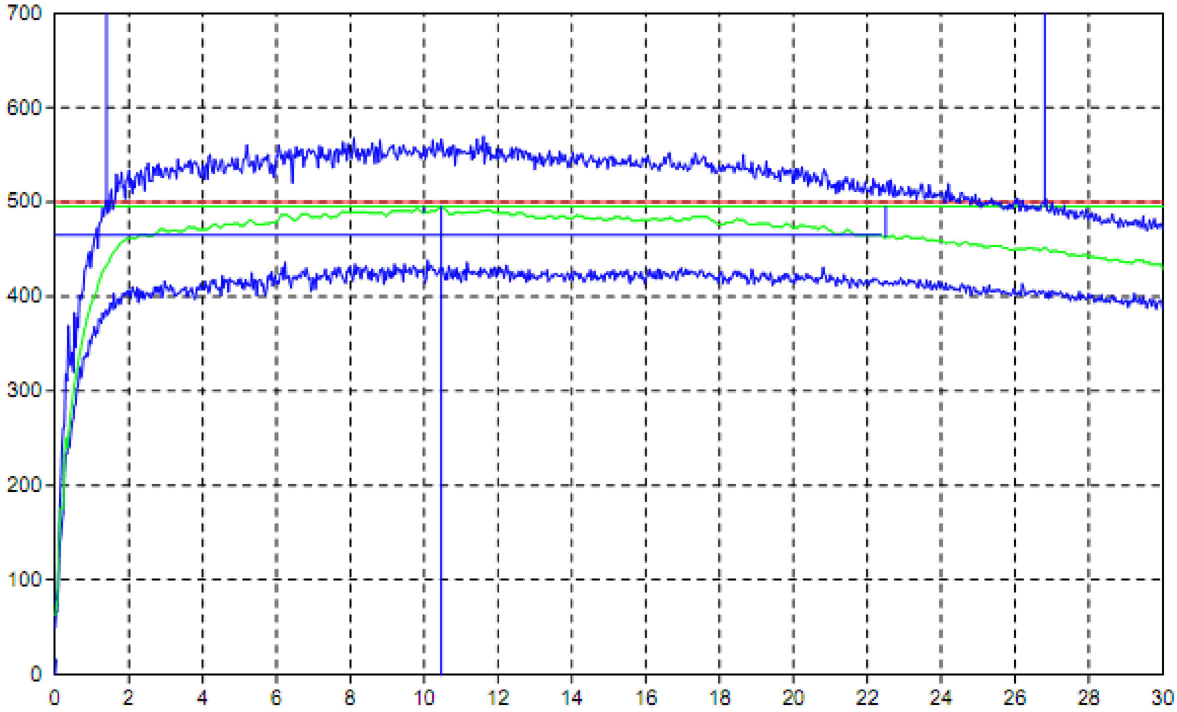

Fig. 35: Farinogram at 1,5 % mas salt addition

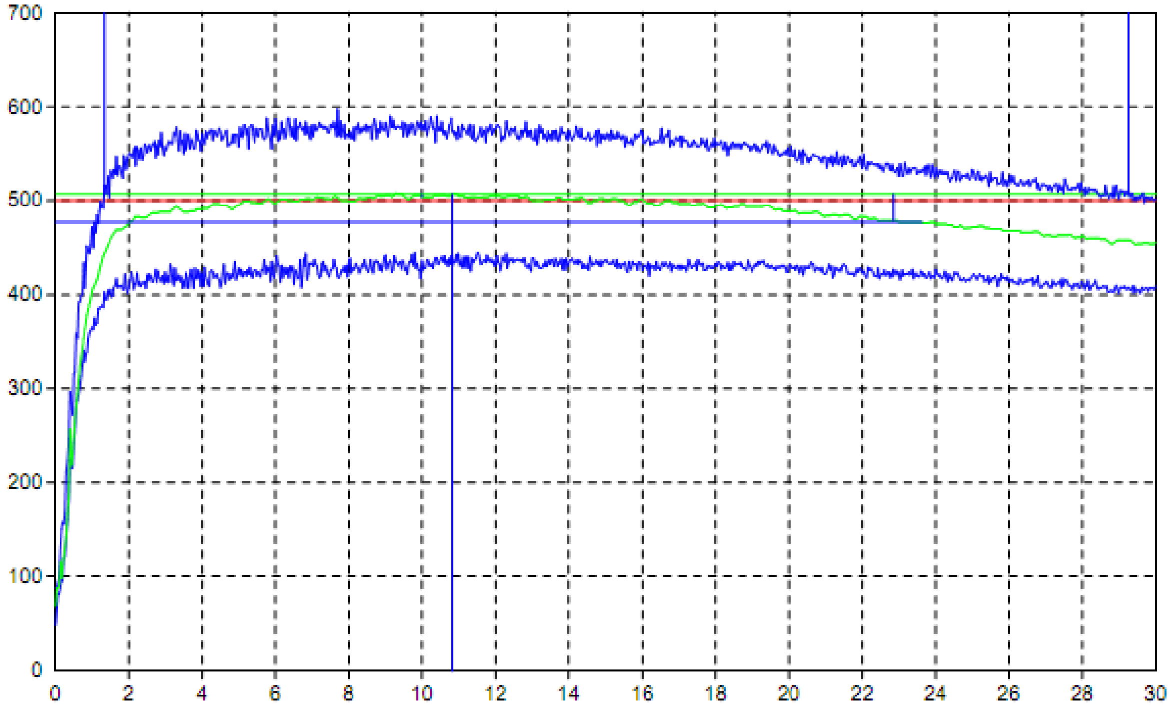

Fig. 36: Farinogram at 1,7 % mas salt addition

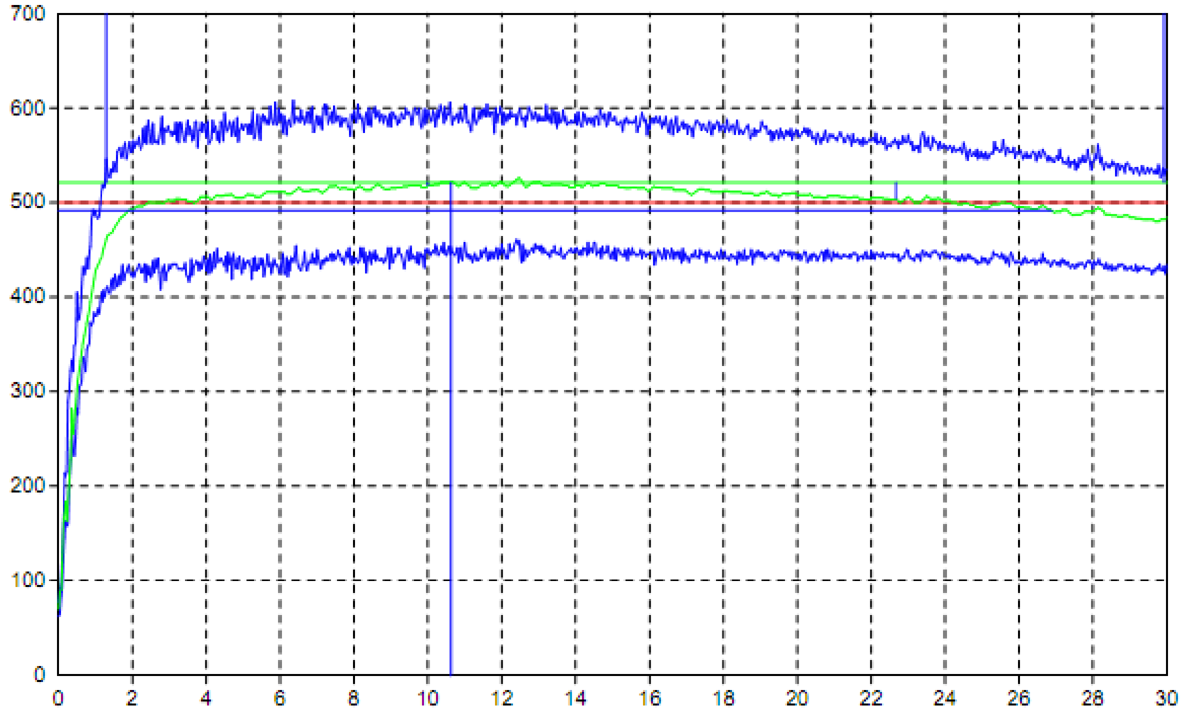

Fig. 37: Farinogram at 2 % mas salt addition

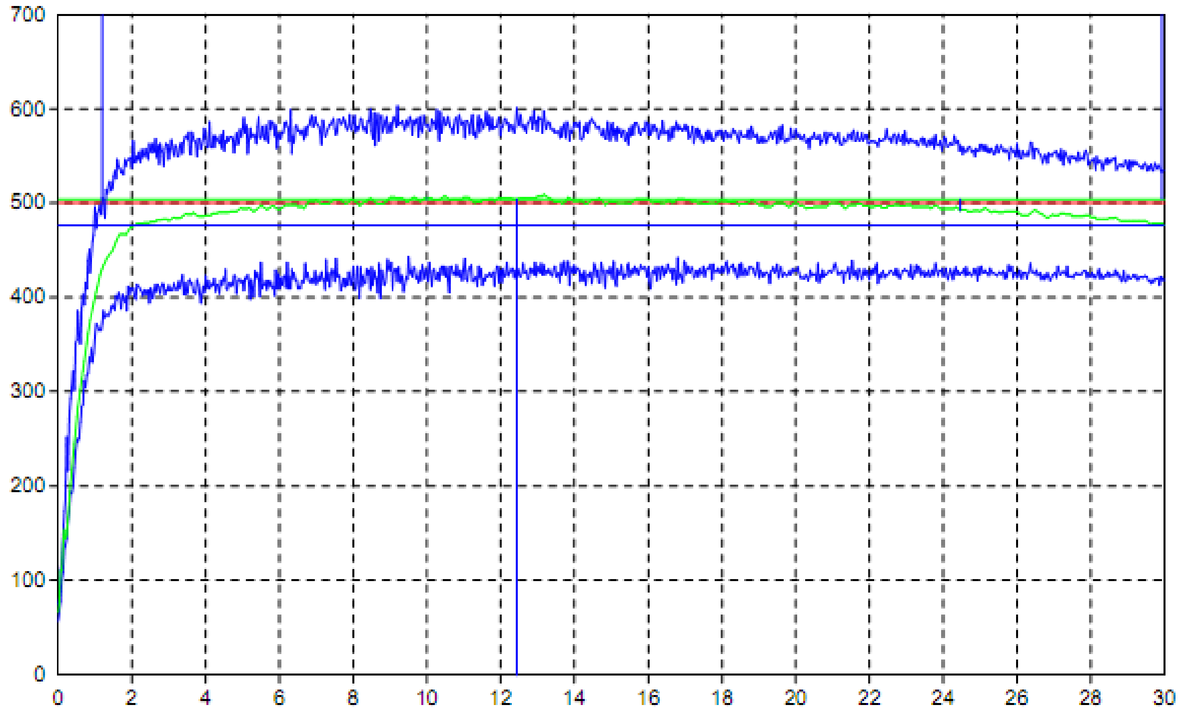

Fig. 38: Farinogram at 2,5 % mas salt addition

18.3 TEST PROTOCOL FOR SENSORY DEGUSTATION ON THE EXAMPLE OF MIXED RYE-BREAD

Roggenmischbrot

Frage 1

Alter:

Geschlecht:

1. Sie erhalten 4 Proben Roggenmischbrot. Bitte testen Sie die 4 Proben in der am Tablett vorgegebenen Reihenfolge von links nach rechts: Rang 1 erhält die Probe, die sie am meisten bevorzugen, Rang 4 jene, die Sie am wenigsten bevorzugen.
2. Neutralisieren Sie den Gaumen zwischen den Proben mit Wasser.
3. Bitte bewerten Sie die Proben anhand ihres Geschmacks und NICHT nach ihrem Aussehen oder Geruch.
4. Rückkosten ist erlaubt, nachdem Sie alle Proben durchgekostet haben.
5. Es können auch GLEICHE Rangplätze vergeben werden.

Bevorzugung/Geschmack				
Probennummer	**1** schmeckt am besten	**2**	**3**	**4** schmeckt am wenigsten
929				
347				
796				
268				

(Zutreffendes bitte ankreuzen!)

Frage 2

1. Bitte testen Sie die 4 Proben in der am Tablett vorgegebenen Reihenfolge von links nach rechts: Rang 1 erhält die Probe, die am wenigsten salzig schmeckt, Rang 4 jene, die am meisten salzig schmeckt.
2. Neutralisieren Sie den Gaumen zwischen den Proben mit Wasser.
3. Bitte bewerten Sie die Proben anhand ihres Geschmacks und NICHT nach ihrem Aussehen oder Geruch.
4. Rückkosten ist erlaubt, nachdem Sie alle Proben durchgekostet haben.
5. Es können auch GLEICHE Rangplätze vergeben werden.

Salzigkeit				
Probennummer	**1** am wenigsten salzig	**2**	**3**	**4** am meisten salzig
929				
347				
796				
268				

(Zutreffendes bitte ankreuzen!)

18.4 RESULTS OF THE BREAD AND ROLL DEGUSTATION

Tab. 26: Friedman Test for salt preference in mixed rye-bread

Ranks

	Mean Rank
1,5% mas	2,60
1,7% mas	2,40
2,0% mas	2,47
2,5% mas	2,53

Test Statistics (Friedman Test)

N	73
Chi-Square	1,177
df	3
Asymp.Sig.	,758

Tab. 27: ANOVA incl. post hoc Tukey Test for salt preference in mixed rye-bread

Preference rating

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2,750	3	,917	,820	,483
Within Groups	321,781	288	1,117		
Total	324,531	291			

Tukey HSD

salt level	N	Subset for alpha = .05
1,7 % mas	73	2,14
2,0 % mas	73	2,27
2,5 % mas	73	2,29
1,5 % mas	73	2,41
Sig.		,400

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 73,000.

Tab. 28: Friedman Test for ranking mixed rye-bread due to its saltiness

Ranks

	Mean Rank
1,5 % mas	2,15
1,7 % mas	2,29
2,0 % mas	2,48
2,5 % mas	3,08

Test Statistics (Friedman Test)

N	73
Chi-Square	24,197
df	3
Asymp. Sig.	,000

Tab. 29: Wilcoxon Test for significance of saltiness ranking in mixed rye-bread samples

Test Statistics(c)

	1,5% mas – 1,7% mas	2,0% mas – 1,5% mas	2,5% mas – 1,5% mas	2,0% mas – 1,7% mas	2,5% mas – 1,7% mas	2,5% mas – 2,0% mas
Z	-,847(a)	-1,588(b)	-3,929(b)	-,891(b)	-3,412(b)	-3,184(b)
Asymp. Sig. (2-tailed)	,397	,112	,000	,373	,001	,001

a Based on positive ranks.
b Based on negative ranks.
c Wilcoxon Signed Ranks Test

Tab. 30: Nemenyi's post-hoc Test for significance of saltiness ranking in mixed rye-bread samples

Saltiness - pairing	Absolute mean rank difference	Significance	Probability	Critical value	Critical Difference
1,5 – 1,7	|2,15 - 2,29| = 0,14	n.s.	0,10%	16,27	0,86
1,5 – 2,0	|2,15 - 2,48| = 0,33	n.s.	1%	11,34	0,72
1,5 – 2,5	|2,15 - 3,08| = 0,93	***	5%	7,81	0,60
1,7 – 2,0	|2,29 - 2,48| = 0,19	n.s.			
1,7 – 2,5	|2,29 - 3,08| = 0,79	***			
2,0 – 2,5	|2,48 - 3,08| = 0,60	**			

Tab. 31: Friedman Test for salt preference in kaiser rolls

Ranks

	Mean Rank
2,5 % mas	2,33
1,7 % mas	2,50
1,5 % mas	2,56
2,0 % mas	2,61

Test Statistics (Friedman Test)

N	64
Chi-Square	2,000
df	3
Asymp. Sig.	,572

Tab. 32: ANOVA incl. post hoc Tukey Test for salt preference in kaiser rolls

Rating scale

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2,262	3	,754	,708	,548
Within Groups	268,453	252	1,065		
Total	270,715	255			

Tukey HSD

salt level	N	Subset for alpha = .05
2,5 % mas	64	2,23
2,0 % mas	64	2,39
1,7 % mas	64	2,44
1,5 % mas	64	2,48
Sig.		,519

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 64,000.

Tab. 33: Friedman Test for ranking kaiser rolls due to their saltiness

Ranks

	Mean Rank
2,5 % mas	3,23
1,7 % mas	2,12
1,5 % mas	2,00
2,0 % mas	2,66

Test Statistics (Friedman Test)

N	64
Chi-Square	40,767
df	3
Asymp. Sig.	,000

Tab. 34: Wilcoxon Test for significance of saltiness ranking in kaiser roll samples

	1,5% mas – 1,7% mas	2,0% mas – 1,5% mas	1,5% mas – 2,5% mas	2,0% mas – 1,7% mas	1,7% mas – 2,5% mas	2,0% mas – 2,5% mas
Z	-,656(a)	-2,923(b)	-4,682(a)	-2,854(b)	-4,596(a)	-2,632(a)
Asymp. Sig. (2-tailed)	,512	,003	,000	,004	,000	,008

a Based on positive ranks.
b Based on negative ranks.
c Wilcoxon Signed Ranks Test

Tab. 35: Nemenyi's post hoc Test for significance of saltiness ranking in kaiser roll samples

Saltiness - pairing	Absolute mean rank difference	Significance	Probability	Critical value	Critical difference
1,5 – 1,7	│2,00 - 2,12│ = 0,12	n.s.	0,1%	16,27	0,92
1,5 – 2,0	│2,00 - 2,66│ = 0,66	**	1%	11,34	0,77
1,5 – 2,5	│2,00 - 3,23│ = 1,23	***	5%	7,81	0,64
1,7 – 2,0	│2,12 - 2,66│ = 0,54	n.s.			
1,7 – 2,5	│2,12 - 3,23│ = 1,11	***			
2,0 – 2,5	│2,66 - 3,23│ = 0,57	*			

19 CURRICULUM VITAE

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PERSÖNLICHE INFORMATION:

Geburtsname:	Hinteregger
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Geburtsort:	Villach
Eltern:	Hildegard und Reinhold Hinteregger
Familienstand:	ledig
Staatsbürgerschaft:	Österreich

AUSBILDUNG:

seit 2005	Hauptuniversität Wien Diplomstudium der Ernährungswissenschaften; Wahlschwerpunkt: Lebensmittelproduktion u.-technologie
1995 - 2003	Gymnasium BG Porcia Spittal/Drau
1991 - 1995	Volksschule Bad Kleinkirchheim

FERIAL- und NEBENJOBS:

seit 2009	Laborantin in der Versuchsanstalt für Getreideverarbeitung (VfG), Wien
2008-2009	Kommissioniererin im Logistikpark 19, Wien
2007 (Juni-Sept.)	Kellnerin, Thekenkraft u. Eisverkäuferin im Café Sommerzeit, Kitzbühel
2001 - 2006 (je Juli-Sept.)	Kellnerin, Thekenkraft, Köchin u. Eisverkäuferin im Café/Pizzeria Moro; Velden
2004 - 2005 (Dez.-Juli)	Ladnerin, Verkäuferin u. Helferin in der Bäckerei Risslegger, Hallein
2004 (Mai-Juli)	Thekenkraft im Hotel Seevilla, Millstatt
2003 - 2004 (Okt.-Mai)	Au-pair in Lausanne, Schweiz

SPRACHKENNTNISSE:

Deutsch	Muttersprache, ausgezeichnete Kenntnisse in Wort und Schrift
Englisch	sehr gute Kenntnisse, in Wort und Schrift
Französisch	gute Kenntnisse, in Wort und Schrift

INTERESSEN und HOBBIES

Klettern, Wandern, Snowboarden, Reisen, Sprachen, Musik