D 5.1 Report on laboratory results

Proposal acronym:	NanoBAK 2
Proposal full title:	Innovative and energy-efficient proofing/cooling technology based on ultrasonic humidification for high quality bakery products
Grant agreement no.:	613622
Work package no.:	5
Work package name:	Laboratory testing of the prototypes
Document prepared by:	ttz Bremerhaven

Table of contents

1. Introduction ... 3
2. Characteristic assessment parameters ... 4
   - 2.1 Stickiness of the dough pieces after proofing ... 4
   - 2.2 Drying-out zone after baking ... 4
   - 2.3 Weight ... 4
   - 2.1 Crust thickness after baking ... 5
   - 2.2 Pore structure and pore size ... 5
   - 2.3 Volume ... 6
   - 2.4 Photodocumentation ... 6
3. Prototype ... 7
4. Recipes and processes ... 9
5. Evaluation ... 11
   - 5.1 Optimization of the delivered prototype ... 11
   - 5.2 trials with adapted parameters ... 12
   - 5.3 trials with same parameters of 35°C and a relative humidity of 80% ... 19
   - 5.4 trials with same parameters of 35°C and a relative humidity of 96% ... 26

1. Introduction

The used technology in the prototypes means a special humidification system: ultrasonic humidification. Small droplet sizes with diameters between 1-2 µm are produced by using acoustic waves at frequencies between 1.7-2.5 MHz in a piezoelectric transducer. A certain volume of water that is placed above the transducer makes the water start vibrating, at the water's surface, small waterdroplets are riped out of the volume. Because of the small droplet sizes, the droplets evaporate immediately, when there is the thermodynamically possibility. Due to this, a high relative humidity (rH) up to 99 % is reachable, even at low temperatures. Furthermore, the effect of evaporating water droplets allows to use a special cooling-principle: adiabatic cooling. The evaporation quickly removes a large quantity of energy out of the products.
The ultrasonic humidification technology is used in the field of bakeries. The proofing stage as well as the cooling stage can be influenced and optimized. Due to the ultrasonic humidification the energy consumption for humidification is reduction massively and the improved mass and heat transfer leads to a reduction in process time as well. Another advantage of using the UltraBAK technology is the improved product quality as a result of the high relative humidity (no drying out and splittering of the crust, increasing windowing, brightness, longer freshness and shelf live and crispness).

Tests with a mobile prototype GA 40/60 featured with the ultrasonic humidification system have been performed to analyze the technical processes such as improved product quality and reduced energy consumption. The tests were performed in comparison to a conventional electrical humidifed proofing chamber with same dimensions.
It was planned to make tests with two different products: wheat rolls and 'Weltmeisterbrot' a kind of wheat whole grain bread. Because of having problems with the prototype after delivery, in this deliverable 5.1 only tests with rolls were described.
An evaluation of the products took places after three times processing as defined in Del 1.2 and 1.3 by using sensorial and optical assessments and on the other hand technical methods.
The technical description is done with technical equipment like VolScan and CCell to generate scientific data for the underlay the optical and sensorial way analyses. Furthermore the weight of the ready baked produces is documented in comparison humidified and non-humidified process.

2. Characteristic assessment parameters

The effect of using the ultrasonic humidification technology for the different kinds of proofing can only be analyzed when having a description of the products during the whole process. The relevant parameters detected during the tests are described below.

2.1 *Stickiness of the dough pieces after proofing*

This parameter has to be documented after the proofing stage. The products proofed by using the ultrasonic humidification system should be stickier than the products in the conventional chamber due to dry out effects in conventional chambers. The resulting formation of a skin at the products surface can be avoided with the high relative humidity generated with the ultrasonic humidification system.

The assessment of the stickiness is performed by contacting the dough pieces with the hand. During deducting the hand slowly from the dough pieces' surface it will be visible if party of the dough piece stick to the hand. To document the effect, a photo will be taken showing if the dough sticks on the hand or not.

Furthermore a description with an assessment scale is possible. This scale is from low stickiness (1 point, dry) to high stickiness (8 points, wet) see Del 1.3 – Documentation protocol.

2.2 *Drying-out zone after baking*

By taking one of the two halves could be seen if the product offers a drying-out zone. The drying out zone is between crust and crumb visible as small white stripe.

For the evaluation of bread some specific parameters have to be considered. This could be the part of flour which is on the surface after baking.

2.3 *Weight*

The effect of the ultrasonic humidification technology is visible in the weight after proofing and baking. Products which are proofed in the prototype with ultrasonic humidification should not lose as much weight as products proofed in the prototype with electrical humidification.

2.1 *Crust thickness after baking*

The ready baked product is divided horizontal into two halves. The part starting with outer crust and ending there where the lighter crumb start is defined is crust. With measuring this distance the thickness of the crust could be evaluated (see picture).

2.2 *Pore structure and pore size*

The pore structure and pore size are analysed after baking. Therefore products of the ultrasonic humidified process and products of the electrical humidified process have to be cut in a horizontally. The pore structure, size and distribution are evaluated and a photo is taken. Additionally, a description with an assessment scales is possible. These scales range from "unequal" (1 point) to "equal" (8 points) concerning the structure of the crumb and "small" "large" in terms of pore-size.

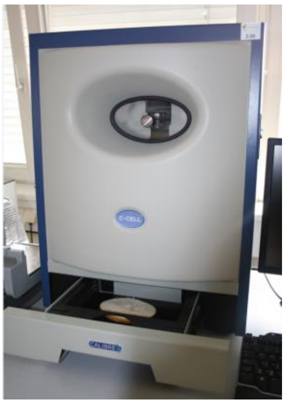
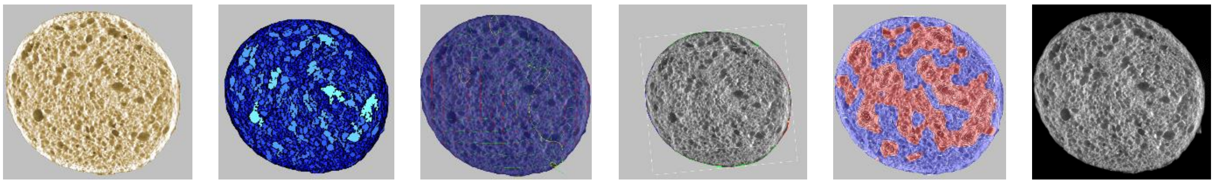


Figure 1: CCell from Calibre (above is the camera and below a drawer in which the product is placed)

Another possibility to assess the pore structure and size is provided by technical device called "CCell" from Calibre. The main part of the CCell is a special camera. The horizontally cut product is placed under the camera as shown in Figure 1. The camera automatically takes detailed and special photos of the product. The CCell analyses the photos and generates some special designs. The pictures (modes) are called "brightness", "cell", "elongation", "shape" and "volume". Of course, a "real photo" is generated as well. Furthermore the software detects the number, the deepness, brightness, shape, volume of pores and further values with which an assessment of the products' quality can be made. An important criterion for the evaluation of the products is the 'number of cells': the higher the number, the better the pore structure and pore size (more equal). Figure 2 shows the different analytic modes. The holes or pores are accentuated in colors. Very large and depth holes are marked brighter than small holes.

By consideration of the cell mode, brightener areas show large pores and yellow areas detected built holes.



brightness cell elongation shape volume ‘real photo’

Figure 2: Overview of the different analytic modes of the CCELL system

2.3 Volume

The products’ volume firstly is assessed optically after proofing. Therefore of products of prototype the electrical humidification and with ultrasonic humidification were taken pictures with defined camera adjustments and positions for being comparable. After the baking stage, the products are evaluated in the same way. Additionally, the products’ volume (V [ml]) is measured by using the VolScan from Stable Microsystems. The VolScan is a technical device which analyses the product with a laser and detects its volume. Therefore, the baked product is fixed in the VolScan like shown in Figure 3. Furthermore the weight of the product is measured, so that the weight and the volume of the product are known and the specific product volume can be calculated:

$V_{specific}$ [ml / g] = V [ml] / m [g]

With this technology the volume as well as the specific volume is detected exactly which gives a comprehensive and objective overview of the products’ quality in terms of the specific volume.

Figure 3: VolScan with clamped roll. The laser scan drives round the product to detect the volume

2.4 Photodocumentation

Finally all products were evaluated with pictures to have a visible comparison of ultrasonic humidified and non-ultrasonic humidified processes. For this kind of evaluation defined parameters of light and distance between product and camera has to be defined.

3. Prototype

In ttz a mobile prototype was tested. The chassis of the prototype is the GA 40/60 with wheels to be mobile and flexible. The outside dimensions of the prototype are measured with 695 mm*876 mm* 2160 mm. 18 plug-in units for baking sheets with dimensions of 40 cm * 60 cm are available.

The process temperature range is adjustable between -18°C and +35°C. The adjustable relative humidity range is between 60-99% and an ultrasonic humidification is possible down to temperatures of -10°C

The technical specification and the technical drawing:

- *mobile chamber:*
  - dimensions outside: 695 x 876 x 2160 mm
  - on wheels for having a mobile and flexible chamber
  - dimension of sheets: 40 cm x 60 cm
  - temperature range between -20°C and +40°C
  - humidities of 65 – 95% should be adjustable and available
  - freezing agent: R404a (without CFC)
  - refrigeration capacity at -10°C: 1075 watt
  - humidify with UltraBAK down till -10°C
  - additionally an electrical humidifier for comparison

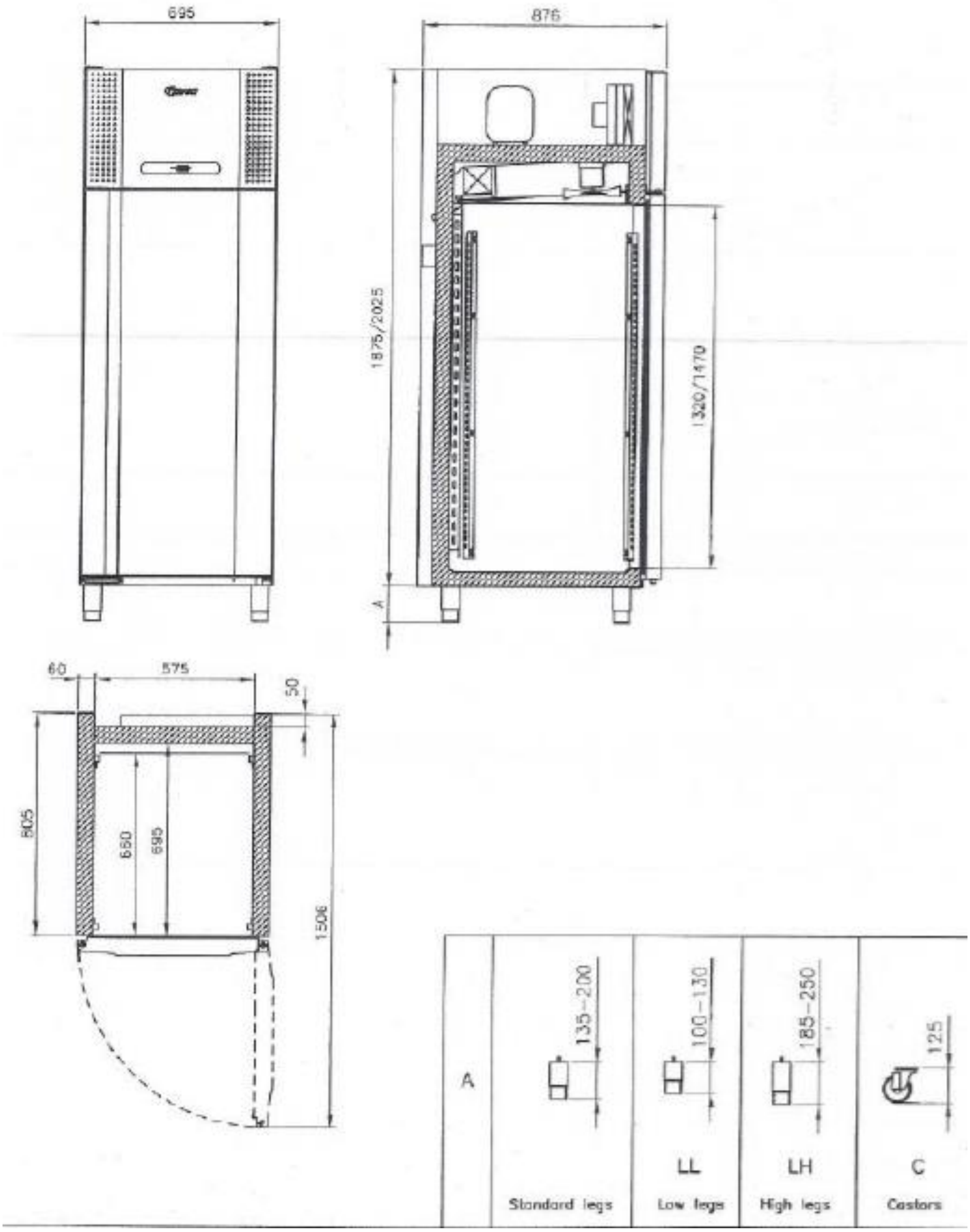


Figure 4: Technical drawing of the mobile prototype of ttz

4. Recipes and processes

This chapter describes the recipe of the products and the used processes:

Rolls

ingredient	part
flour type 550	100
salt	2
yeast	3
improver	3
water	58

For the rolls three different kinds of proofing were executed: direct proofing, interrupted proofing and retarded proofing for ultrasonic and electrical humidification.
Because of having influence on the process by using ultrasonic humidification, the process parameters has to be adapted:

Proofing processes with electrical humidification:

proofing: 40-45 Minutes, 35°C, 80% rel. humidity

retarded proofing:

stage	temperature	time	rel. humidity
retarded proofing	+3°C	10 hours	75% rH
proofing 1	+10°C	4,5 hours	75% rH
proofing 2	+18°C	2,5 hours	75% rH

interrupted proofing:

stage	temperature	time	rel. humidity
interrupted proofing	-18°C	1 hours	
interrupted proofing	-10°C	12 hours	75% rH
heating phase	+3°C	10 hours	75% rH
proofing 1	+10°C	4,5 hours	75% rH
proofing 2	+18°C	2,5 hours	75% rH

Proofing processes with ultrasonic humidification:

proofing: 40-45 Minutes, 28°C, 96% rel. humidity

retarded proofing:

stage	temperature	time	rel. humidity
retarded proofing	+3°C	10 hours	96% rH
proofing 1	+10°C	3 hours	96% rH
proofing 2	+18°C	2 hours	96% rH

interrupted proofing:

stage	temperature	time	rel. humidity
interrupted proofing	-18°C	1 hours	
interrupted proofing	-10°C	12 hours	96% rH
heating phase	+3°C	10 hours	96% rH
proofing 1	+10°C	3 hours	96% rH
proofing 2	+18°C	2 hours	96% rH

5. Evaluation

5.1 Optimization of the delivered prototype

After delivery of the prototype and first trials with unexpected results, an error diagnostic as well as an optimization of the prototype was done:

In the error diagnostic, the following points were detected:

- Inhomogeneous temperature distribution, difference of 1.5-9°C between top and bottom of the prototype
- Presence of aerosol depends on speed of van
- Strong water condensation inside the prototype
- Water condensation next to the van
- Condensate dropped out of the aerosol inlet
- Problems with aerosol production, after a short time the produces aerosols decreased until complete absence.

Because of the identified points of the error diagnostics, an optimization of the prototype was conducted.

Own optimizations were done by ttz:

For the sample of the condensate water the u-tube was optimized and a sample tube was added. Furthermore, a drainage system on the bottom of the chamber was constructed.

The measurement points of temperature and humidity were changed more central in the chamber to have equal temperatures overall in the chamber

The most important optimization was conducted by Ungermann: the van's run directed was changed because it was wrong connected. After this optimization an optimized air flow and distribution of aerosols as well as a well working prototype was generated and trials with rolls could be executed.

5.2 *trials with adapted parameters*

The trials with process specific adapted parameters were conducted to see the influence of both technology by conventional or/and optimal process parameters for ultrasonic humidification. This means for example, that in the direct proofing the process temperature could be reduced from 35°C down to 28°C by having higher relative humidity that leads to an energy reduction. The adapted parameters were based on further experiences with the ultrasonic humidification technology.

Direct proofing:

The following attributes could be seen after the proofing stage with ultrasonic humidification (28°C; 96% relative humidity) in comparison to the electrical humidified proofing process (35°C, 80% relative humidity).

Table 1: summary of the appearance of dough pieces after proofing (with and without ultrasonic humidification)

Conventional proofing	**Ultrasonic humidified**
Skin formation	No skin formation, surface dry but not sticky
Drying out of surface	Shape stability of the dough piece after proofing
Weight loss	No weight loss after proofing
Stick on the trolley	Does not stick on the trolley

The evaluation after baking showed that the products proofed with ultrasonic humidification (right) offered (Figure 5):

- More equal browning
- Better crust and split
- More intense windowing

Figure 5: Comparison of the products proofed with electrical humidification (left) and ultrasonic humidification (right) in the direct proofing process

The evaluation of specific volume (VolScan) and pore characterisation (CCell) showed that the product of the ultrasonic based proofing process leads to an increasing specific volume and finer pores. (BDK – rolls from conventional proofing; BDN – rolls from ultrasonic humidified proofing process).

Figure 6 shows that the ultrasonic humidified proofing process leads to an average specific volume of 4.72 ml^3/g in comparison to conventional proofed roll with an average specific volume of 4.61 ml^3/g (number of measured samples for calculation the specific volume = 20 rolls per process).

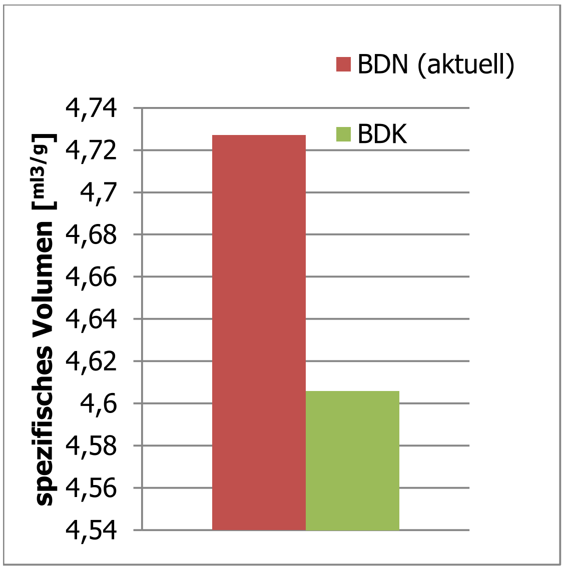


Figure 6: comparison of average specific volume of direct proofed products (with and without ultrasonic humidification)

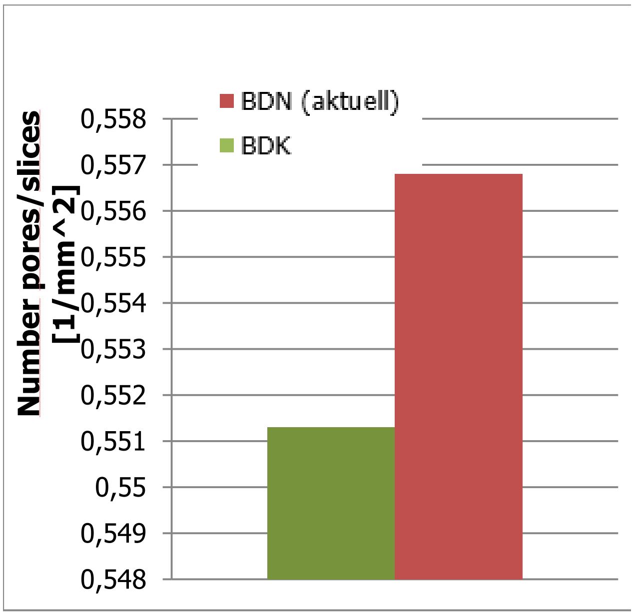


Figure 7: comparison of pore characterisation (the higher the factor, the finer the pores) of direct proofed products (with and without ultrasonic humidification)

The evaluation of the pore characterization shows that the number of pores/slices leads to an average factor of 0.557 (NanoBAK2 process) in comparison to 0.551 (conventional process) in Figure 7. This means that a little bit more and therefore finer pores were present in one slice $1/mm^2$ of the ultrasonic humidified proofed roll (number of measured samples for calculation the specific volume = 20 rolls per process).

retarded proofing:

The following attributes could be seen after the proofing stage with ultrasonic humidification in comparison to the electrical humidified retarded proofing process.

Table 2: summary of the appearance of dough pieces after retarded proofing (with and without ultrasonic humidification)

Conventional proofing	**Ultrasonic humidified**
Skin formation	No skin formation, surface dry but not sticky
Drying out of surface	Shape stability of the dough piece after proofing
Weight loss	No weight loss after proofing

The evaluation after baking showed that the products retarded proofed with ultrasonic humidification (right) offered (Figure 8):

- More equal browning
- No dark areas on the surface
- Better windowing

Figure 8: Comparison of the products proofed with electrical humidification (left) and ultrasonic humidification (right) in the retarded proofing process

The evaluation of specific volume (VolScan) and pore characterisation (CCell) showed that the product of the ultrasonic based proofing process leads to an increasing specific volume (GVK – rolls from conventional proofing; GVN – rolls from ultrasonic humidified proofing process).

Figure 9 shows that the ultrasonic humidified proofing process leads to an average specific volume of 5.1 ml^3/g in comparison to conventional proofed roll with an average specific volume of 4.7 ml^3/g (number of measured samples for calculation the specific volume = 20 rolls per process).

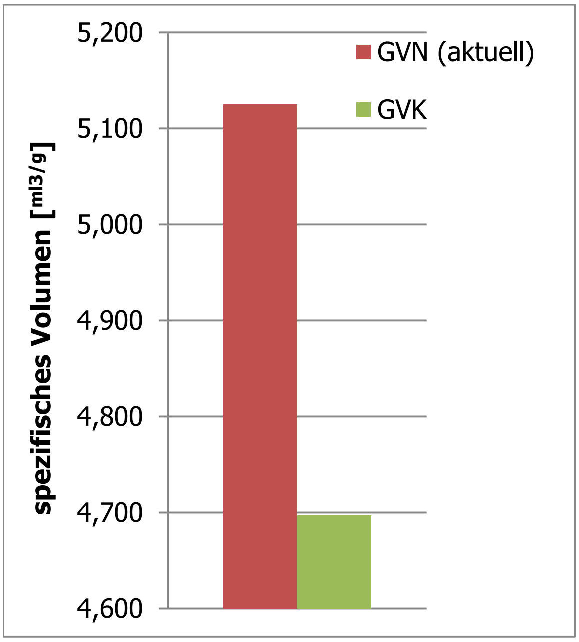


Figure 9: comparison of average specific volume of retarded proofed products (with and without ultrasonic humidification)

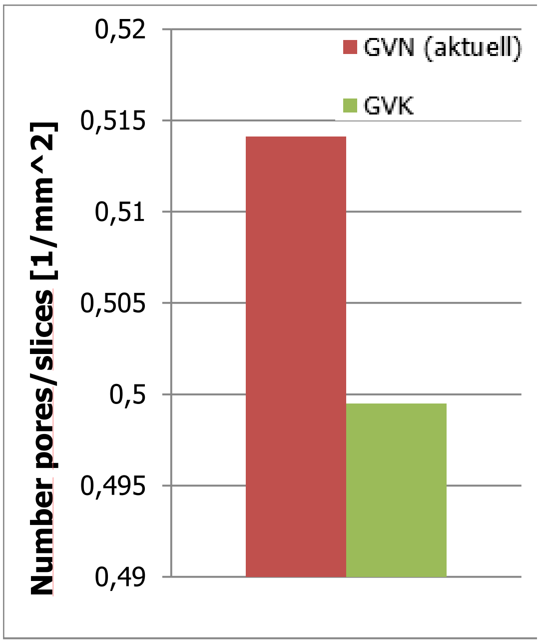


Figure 10: comparison of pore characterisation (the higher the factor, the finer the pores) of retarded proofed

The evaluation of the pore characterization shows that the number of pores/slices leads to an average factor of 0.514 (NanoBAK2 process) in comparison to 0.499 (conventional process) in Figure 10. This means that more and therefore finer pores were present in one slice 1/mm^2 of the NanoBAK2 proofed roll (number of measured samples for calculation the specific volume = 20 rolls per process).

interrupted proofing:

The following attributes could be seen after the interrupted proofing process.

Table 3: summary of the appearance of dough pieces after interrupted proofing (with and without ultrasonic humidification)

Conventional proofing	**Ultrasonic humidified**
Skin formation	No skin formation, surface dry but not sticky
Drying out of surface	Shape stability of the dough piece after proofing
Weight loss	No weight loss after proofing

The evaluation after baking showed that the products interrupted proofed with ultrasonic humidification (right) offered (Figure 11):

- More equal browning
- No dark areas on the surface
- Better windowing
- Better crispness

Figure 11: Comparison of the products proofed with electrical humidification (left) and ultrasonic humidification (right) in the interrupted proofing process

The evaluation of specific volume (VolScan) and pore characterisation (CCell) showed that the product of the ultrasonic based proofing process leads to an increasing specific volume (GVK – rolls from conventional proofing; GVN – rolls from ultrasonic humidified proofing process).

Figure 12 shows that the ultrasonic humidified proofing process leads to an average specific volume of 5.08 ml^3/g in comparison to conventional proofed roll with an average specific volume of 4.76 ml^3/g (number of measured samples for calculation the specific volume = 20 rolls per process).

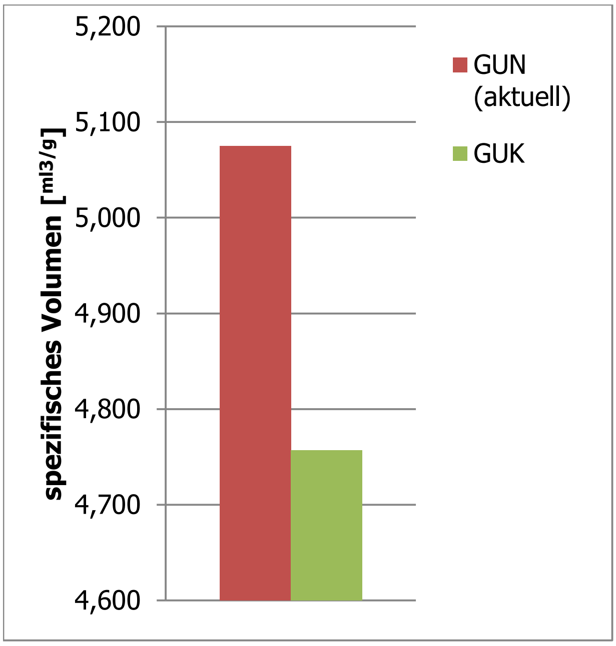


Figure 12: comparison of average specific volume of interrupted proofed products (with and without ultrasonic humidification)

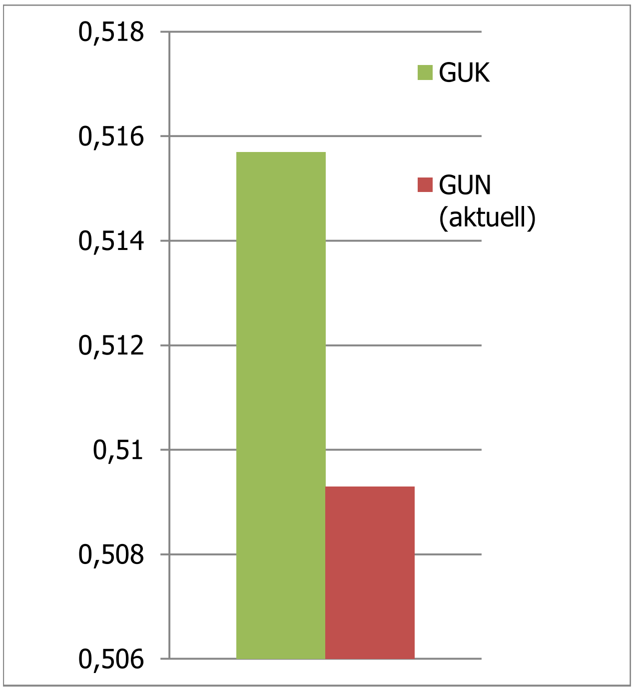


Figure 13: comparison of pore characterisation (the higher the factor, the finer the pores) of interrupted proofed products (with and without ultrasonic humidification)

The evaluation of the pore characterization shows that the number of pores/slices leads to an average factor of 0.509 (NanoBAK2 process) in comparison to 0.519 (conventional process) in Figure 13. This means that more and therefore finer pores were present in one slice $1/mm^2$ of the conventional proofed roll (number of measured samples for calculation the specific volume = 20 rolls per process).

The influence of the ultrasonic aerosols in the interrupted proofing is not so high because of the freezing storage phase. In this phase no humidification takes place.

Summarized it could be said that in the retarded and direct proofing the ultrasonic humidification leads to improved results with a complete executable prototype (no stickiness and skin formation after proofing, better browning, windowing, crispness, crust, freshness, pore structure).

For the interrupted fermentation process, parameter for proofing as well as for baking had to be adapted.

5.3 trials with same parameters of 35°C and a relative humidity of 80%

After executing trials with process adapted parameters trials with same parameters were executed to have a better comparability of the different humidification systems and there influences. Until now a first trial for the direct proofing (with and without aerosol addition) with same parameters was performed: 35°C and a relative humidity of 80%

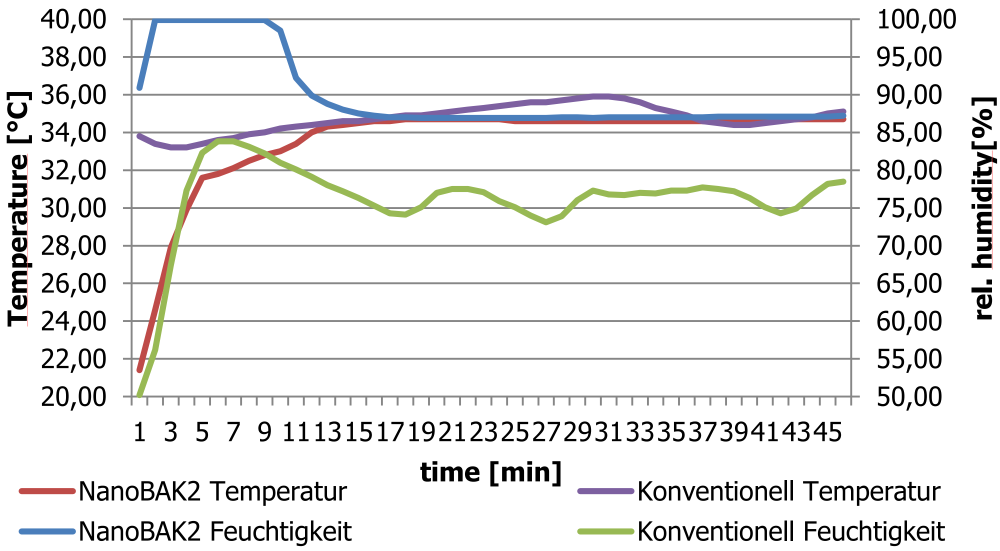


Figure 14: comparison of measured temperature and humidity of both chambers at 35°C and a humidity of 80%

Figure 14 shows the measured temperature and humidity inside the conventional chamber and the NanoBAK2 prototype. The adjusted humidity of 80% was not reached. In the conventional process, the humidity was 75% and in the ultrasonic humidified chamber 87%.
Concerning the temperature of 35°C both chambers were able to held the adjusted temperature.
The influence of the type of humidification on the core temperature (ultrasonic or electrical) is shown in Figure 15.
The products in the prototype offers a maximum core temperature of 32°C because the finest aerosols with a droplet size between 1-5 µm are able to go inside the product and leads to an increasing mass- and heat transfer. In comparison, the core temperature of the electrical humidified products is 30°C at a maximum. Furthermore could be seen, that the core

temperature of the ultrasonic humidified product raised faster because of better mass- and heat transfer.

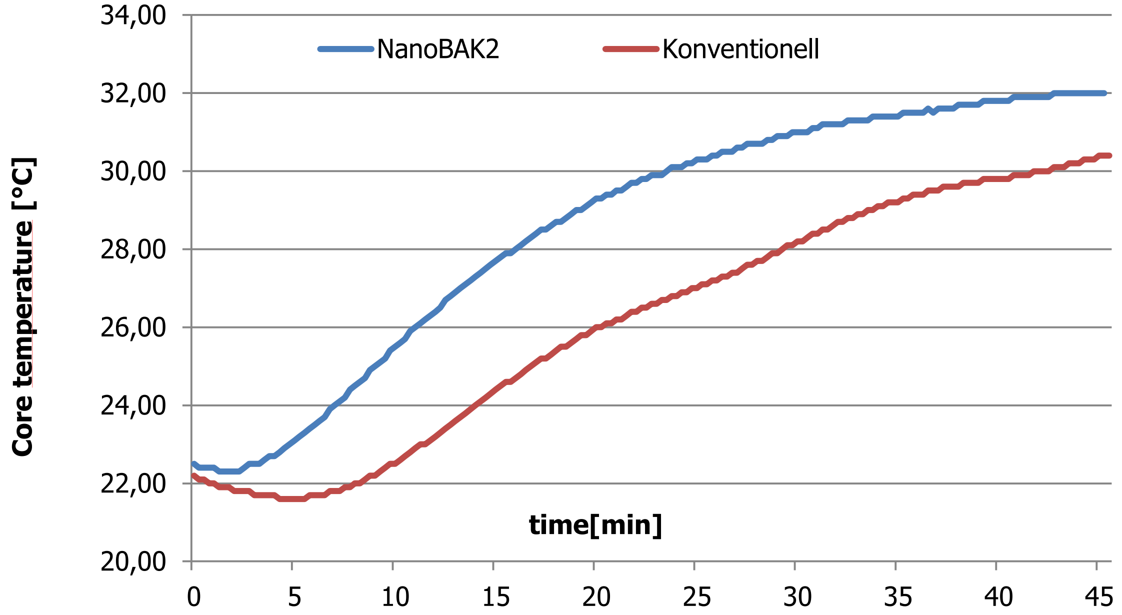


Figure 15: Comparison of the core temperature of the products in a conventional and an ultrasonic humidified chamber at temperatures of 35°C and a humidity of 80%

After proofing was visible that the products of the conventional proofing process offered a skin formation in contrast to the NanoBAK2 products which have no skin on their surface.
By having identical temperatures of 35°C, the surface of the ultrasonic humidified products was a little bit wet but do not stick on their surface.

Concerning product quality after baking an improved oven leaving was visible. Further advantages of the products of the ultrasonic humidified process were (Figure 16):

- better browning
- more equal browning
- better windowing
- larger volume
- better crispness
- better spring

Figure 16: Comparison of direct proofed products at 35°C and a relative humidity of 80% with ultrasonic humidification(left) and conventional electrical humidification (right)

Figure 17 shows the specific volume of the direct proofed products at 35°C and a relative humidity of 80% with ultrasonic humidification and conventional electrical humidification. The products of the ultrasonic humidified process offered an average specific volume of 5.78 m^3/g and the products of the conventional humidified process of 5.35 m^3/g (number of measured samples for calculation the specific volume = 20 rolls per process).

Because of having finer droplet sizes by using ultrasonic generated aerosols in the prototype the aerosols pass inside the dough pieces and increases the enzyme activity in the dough which leads to higher specific volumes. Additional the oven leaving is increased by having an improved heat- and mass- transfer because of the higher water content inside the products.

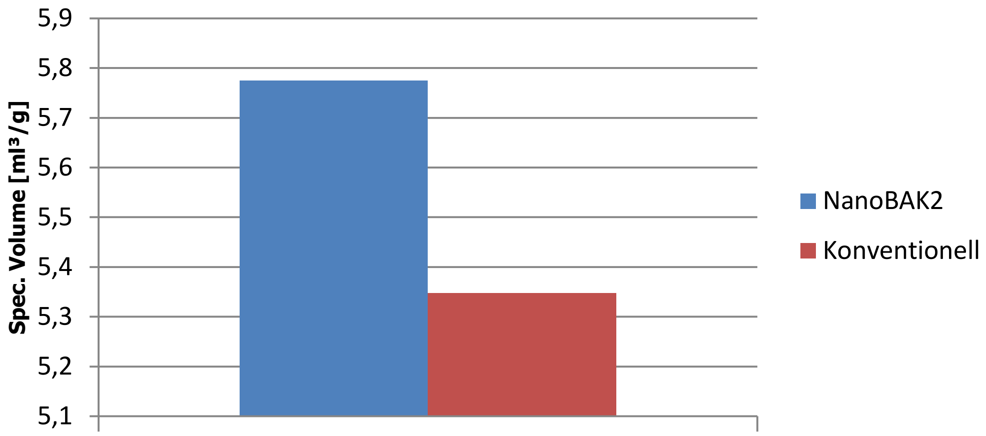


Figure 17: comparison of average specific volume of direct proofed products at 35°C and a relative humidity of 80% with ultrasonic humidification and conventional electrical humidification

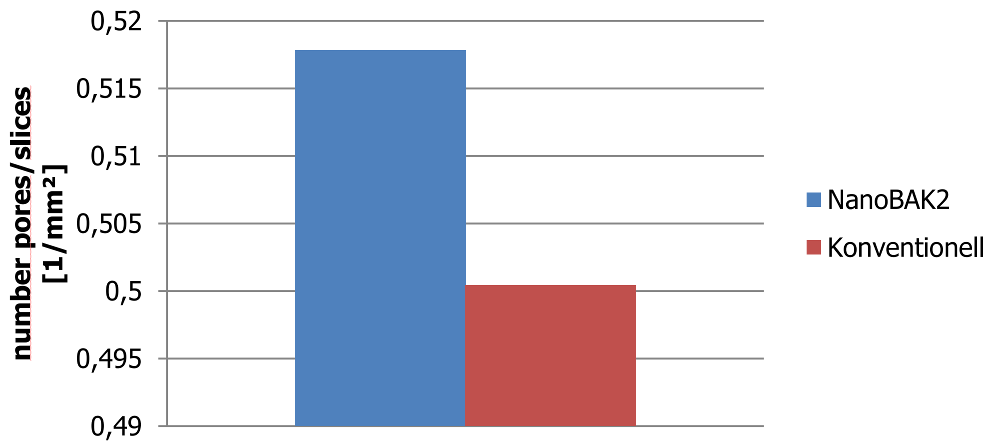


Figure 18: comparison of pore characterisation (the higher the factor, the finer the pores) of direct proofed products at 35°C and a relative humidity of 80% with ultrasonic humidification and conventional electrical humidification

The evaluation of the pore characterization shows that the number of pores/slices leads to an average factor of 0.517 (NanoBAK2 process) in comparison to 0.501 (conventional process) in Figure 18. This means that more and therefore finer pores were present in one slice 1/mm^2 of the ultrasonic humidified proofed roll (number of measured samples for calculation the specific volume = 20 rolls per process.

Table 4 shows the weight loss depending on the different types of humidification at 35°C and a relative humidity of 80%.

Table 4: comparison of weight loss depending on the different types of humidification at 35°C and a relative humidity of 80%

Sample ID	Weight loss during proofing [g]	Weight loss during proofing [%]	Weight before baking [g]	Weight after baking [g]	Weight loss[g]	Baking loss [%]
NanoBAK	-4	-0,5917	676	539	137	20,3
NanoBAK	-5	-0,7622	656	517	139	21,2
NanoBAK	-2	-0,2976	664	527	137	20,6
NanoBAK	-3	-0,4478	670	538	132	19,7
NanoBAK	-1	-0,1506	664	532	132	19,9
average	-3	-0,4499	666	530,6	135,4	20,34

Sample ID	Weight loss during proofing [g]	Weight loss during proofing [%]	Weight before baking [g]	Weight after baking [g]	Weight loss[g]	Baking loss [%]
conventional	-4	-0,4024	672	542	130	19,3
conventional	-4	-0,402	998	802	196	19,6
conventional	-5	-0,502	995	799	196	19,7
conventional	-3	-0,3006	996	795	201	20,2
average	-4	-0,40175	915,25	734,5	180,75	19,7

The weight loss after proofing and baking was detected by documenting the weight loss of one baking sheet with products. After proofing the weight loss of the ultrasonic humidified process is documented with -0.45% in average. The average weight loss of the conventional proofed products was detected with -0.4%. It could be seen that the weight loss during the proofing process is nearly the same.

The weight loss after baking is approximately the same too, but a little bit higher for the ultrasonic humidified products and could be explained by having stronger spring, stronger crust formation as well as a larger volume.

The thickness of crust and drying out zone (see Table 5) was measured by sliding calliper.

Table 5: comparison of crust thickness and drying out zone depending on the different types of humidification at 35°C and a relative humidity of 80%

Crust thickness sample ID	NanoBAK2 [mm]	Conventional [mm]
1	3,09	2,63
2	3,02	2,76
3	2,54	2,63
4	2,96	2,70
5	2,78	2,87
6	2,49	2,51
7	2,44	2,61
8	2,77	2,46
9	2,81	2,69
10	2,82	2,56
average	**2,772**	**2,642**
Drying out zone sample ID	**NanoBAK2 [mm]**	**Conventional [mm]**
1	2,14	2,65
2	2,42	2,82
3	1,79	3,02
4	2,30	2,49
5	1,92	2,65
6	2,76	2,93
7	2,52	2,80
8	2,52	2,76
9	1,80	2,73
10	2,18	2,76
average	**1,983**	**2,761**

The crust of the ultrasonic humidified products after baking is a little bit larger with a thickness of 2.722 mm than the crust of the conventional proofed products (2.642 mm). A thicker crust leads to a better crispness and a longer freshness of the product.

In contrast, the drying out zone of the ultrasonic humidified products is smaller (1.983 mm) than the drying out zone of the conventional proofed products (2.761). The difference of 0.778 mm shows the strong influence of the humidification technology of the product quality. The thinner the drying out zone of a product the fresher is the appearance.

Summarized could be said, that the differences in quality after proofing (35°C and 80% relative humidity) depend directly in the type of humidification. The use of ultrasonic generated aerosols in the NanoBAK2 prototype leads to

- more stable dough pieces after proofing which relieve the following process stages
  - no collapse of the dough after turning
  - higher proofing tolerance and stability
- baking time could be reduced or lower temperature could be used
  - energy reduction
- higher specific volume
- finer pores
- better windowing
- better and more equal browning
- optimized spring
- better crispness

5.4 *trials with same parameters of 35°C and a relative humidity of 96%*

After executing trials with process adapted parameters trials with same parameters were performed to have a better comparability of the different humidification systems and there influences. Until now a first trial for the direct proofing (with and without aerosol addition) with same parameters was performed: 35°C and a relative humidity of 96%

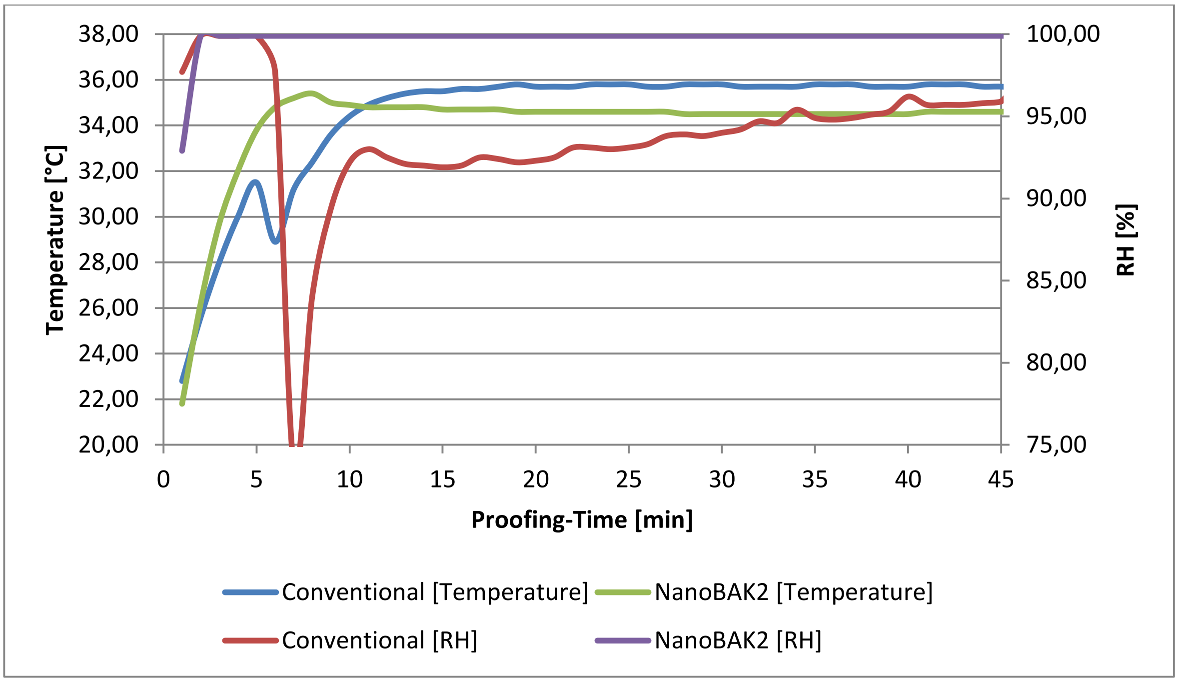


Figure 19: comparison of measured temperature and humidity of both chambers at 35°C and a humidity of 96%

Figure 19 shows the measured temperature and humidity inside the conventional chamber and the NanoBAK2 prototype.

The adjusted humidity of 96% could not be reached. In the conventional process, the humidity was around 92% for 35 minutes. After this time 96% humidity could achieved for the first time. In the ultrasonic humidified chamber the measured humidity was approx. 100%.

Concerning the temperature of 35°C both chambers were able to held the adjusted temperature. But the conventional chamber need a longer time to reach the adjusted temperature.

The influence of the type of humidification on the core temperature (ultrasonic or electrical) is shown in Figure 20.

The core temperature of ultrasonic humidified products reached the surrounding temperature after 45 minutes. Conventional humidified products had a difference of ca. 2°C between core temperature and environmental temperature.
An exemplary chosen temperature, for example 32°C, was reached by ultrasonic humidification at approx. 20 minutes. The conventional humidification needed ca. 35 minutes to reach the same core temperature.

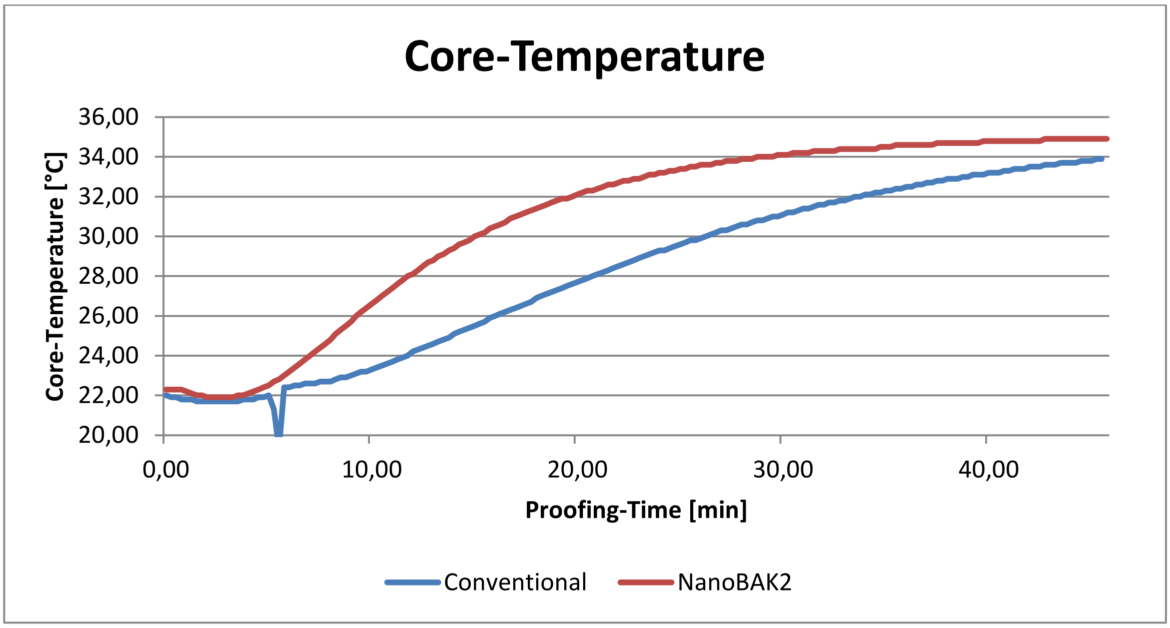


Figure 20: Comparison of the core temperature of the products in a conventional and an ultrasonic humidified chamber at temperatures of 35°C and a humidity of 96%

After proofing was visible that the products of the conventional proofing process offered a skin formation in contrast to the NanoBAK2 products which have no skin on their surface.
By having identical temperatures of 35°C, the surface of the ultrasonic humidified products was dry but do not stick on their surface or the proofing tray as the products of the conventional proofing process did. Furthermore the dough pieces of the NanoBAK proofing process offered a larger volume and seemed to be more stable.

Concerning product quality after baking an improved oven leaving was visible. Furthermore the products of the ultrasonic humidified process offered (Figure 21):

- better browning
- more equal browning
- better windowing
- larger volume

- better crispness
- better spring

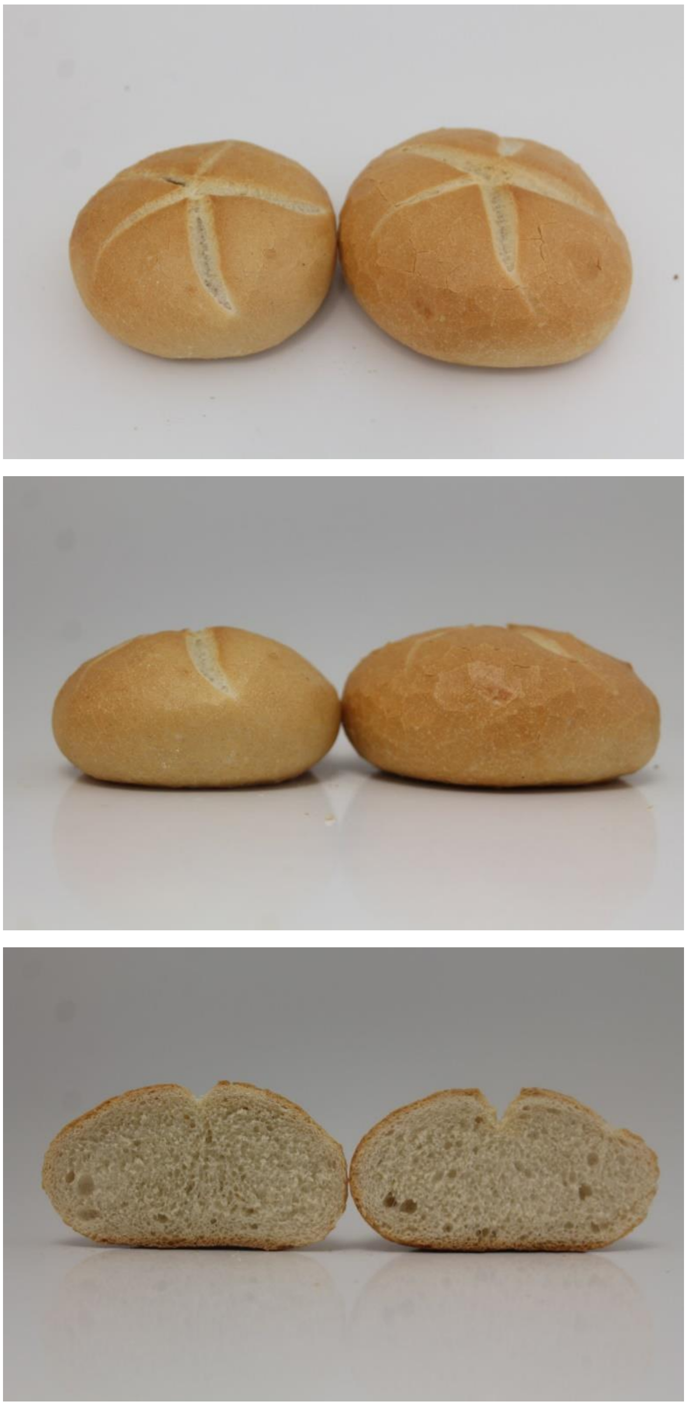


Figure 21: Comparison of direct proofed products at 35°C and a relative humidity of 96% with ultrasonic humidification (right) and conventional electrical humidification (left)

Figure 22 shows the specific volume of the direct proofed products at 35°C and a relative humidity of 96% with ultrasonic humidification and conventional electrical humidification. The products of the ultrasonic humidified process offered an average specific volume of 5.75 m^3/g and the products of the conventional humidified process of 5.05 m^3/g (number of measured samples for calculation the specific volume = 20 rolls per process).

Because of having finer droplet sizes by using ultrasonic generated aerosols in the prototype the aerosols pass inside the dough pieces and increases the enzyme activity in the dough which leads to higher specific volumes. Additional the oven leaving is increased by having an improved heat- and mass- transfer because of the higher water content inside the products.

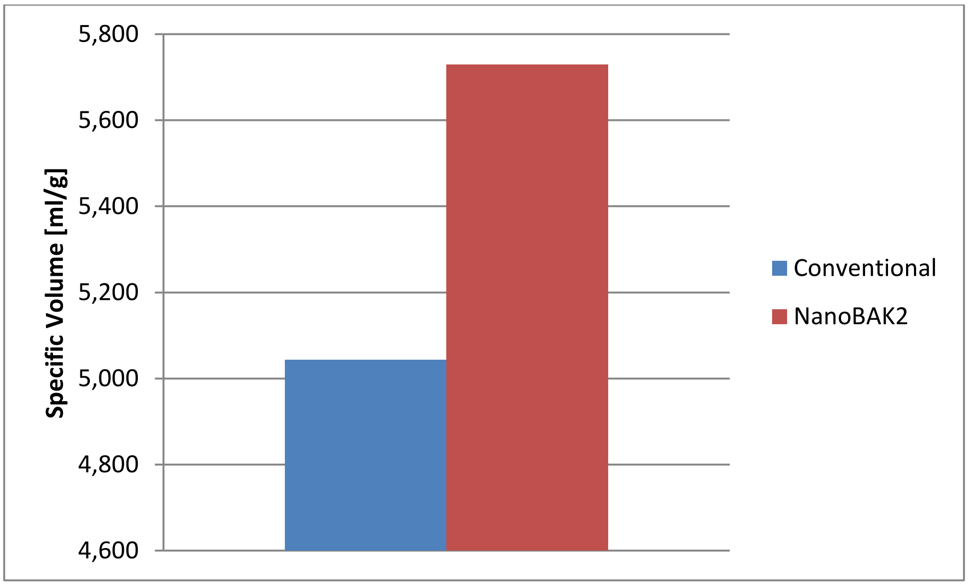


Figure 22: comparison of average specific volume of direct proofed products at 35°C and a relative humidity of 96% with ultrasonic humidification and conventional electrical humidification

The evaluation of the pore characterization shows that the number of pores/slices leads to an average factor of 0.51 (NanoBAK2 process) in comparison to 0.56 (conventional process) Figure 23. This means that more and therefore finer pores were present in one slice $1/mm^2$ of the conventional humidification products. The difference as such is small and is not remarkably seen through optical analysis (number of measured samples for calculation the specific volume = 20 rolls per process.

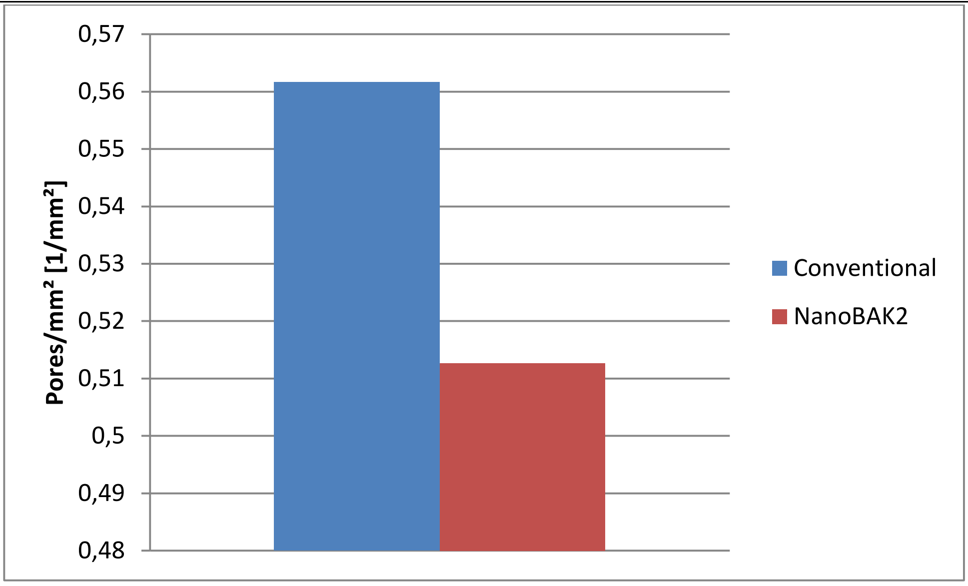


Figure 23: comparison of pore characterisation (the higher the factor, the finer the pores) of direct proofed products at 35°C and a relative humidity of 96% with ultrasonic humidification and conventional electrical humidification

Table 6 shows the weight loss depending on the different types of humidification at 35°C and a relative humidity of 96%.

Table 6: comparison of weight loss depending on the different types of humidification at 35°C and a relative humidity of 96%

Sample ID	Weight loss/gain during proofing [g]	Weight loss/gain during proofing [%]	Weight before baking [g]	Weight after baking [g]	Weight loss[g]	Baking loss [%]
NanoBAK	+4	+0,6	670	533	137	20,45
NanoBAK	+2	+0,3	657	524	133	20,24
NanoBAK	+1	+0,15	664	529	135	20,33
NanoBAK	+2	+0,33	670	535	135	20,15
NanoBAK	+3	+0,42	656	532	124	18,90
average	+2,4	+0,36	663	530,6	132,8	20,01

Sample ID	Weight loss during proofing [g]	Weight loss during proofing [%]	Weight before baking [g]	Weight after baking [g]	Weight loss[g]	Baking loss [%]
conventional	-4	-0,404	999	811	188	18,82
conventional	-4	-0,401	995	799	196	19,67
conventional	-5	-0,503	1006	808	198	19,68
conventional	-3	-0,311	995	795	200	20,10
average	**-4**	**-0,40475**	**998,75**	**803,25**	**195,5**	**19,57**

The weight loss after proofing and baking was detected by documenting the weight loss of one baking sheet with products. After proofing the ultrasonic humidified process led to a weight gain of 0.36% in average. The average weight loss of the conventional proofed products was detected with -0.4%. It could be seen that the using of ultrasonic humidification leads to a weight gain after proofing. In comparison the conventional humidification system for direct proofing resulted in a weight loss of the dough pieces.

The weight loss after baking is approximately the same, but a little bit higher for the ultrasonic humidified products and could be explained by having stronger spring, stronger crust formation as well as a larger volume.

Summarized could be said, that the differences in product quality after a proofing process at 35°C and 96% relative humidity depend directly in the type of humidification. The use of ultrasonic generated aerosols in the NanoBAK2 prototype leads to

- more stable dough pieces after proofing which relieve the following process stages
    - weight gain after proofing instead of weight loss
    - no collapse of the dough after turning
    - higher proofing tolerance and stability
- higher specific volume
- finer pores
- better windowing
- better and more equal browning
- optimized spring
- better crispness

First trials for both processes (direct proofing with same parameters 35°C one time with 80% and one time with 96%) resulted in better quality of ultrasonic humidified products during proofing and documented the influence of the ultrasonic humidification technology in the proofing process on the product quality after proofing as well as after baking. In trials with adapted parameters it could be seen that the use of ultrasonic generated aerosols in the proofing process leads to the possibility to decrease proofing time or temperature with same results of increasing product quality. This offers next to high quality products the opportunity to save time, energy and therefore costs in the products.

Further tests will be performed in the next months (including energy and water consumption) for the three different kinds of proofing (direct, retarded and interrupted) to receive comprehensive results of the influence of the technology by TTZ. Furthermore, trials will be conducted with the world champion ship bread of Bäckerei Sikken and the Baguettes of BPA Nantes to receive comprehensive results with different types of products for evaluate the technology and to spread the knowledge on the European market.