Investigation of 160 spelt varieties on agronomic, dough and baking quality traits

Prof. Dr. Friedrich Longin and Dr. Matthias Rapp, State Plant Breeding Institute, University of Hohenheim, Stuttgart, https://weizen.uni-hohenheim.de

Abstract

Spelt receives more and more popularity in Germany and Europe. The trading and product development of spelt is hindered by the yet still lacking description of quality traits for spelt varieties. To better understand the quality traits and their correlation among each other and to deliver a basis for future spelt quality characterisation, we performed a very large field and laboratory trial, where we tested at three different locations 160 spelt varieties. The spelt varieties comprised very old landraces up to latest breeding lines. After harvest, the nearly 600 samples were intensively analysed in a quality lab comprising farino-, extenso-, and alveograph, sedimentation volume, protein and gluten content as well as a baking test.

We confirmed a large variability for the different varieties regarding almost all traits. Protein as well as gluten content did not correlate with bread loaf volume and thus, both methods cannot be used as rapid test for baking quality in spelt. The correlation between energy value from extensograph and loaf volume was highest in our study with r = 0.86***. Sedimentation volume also highly correlated with loaf volume (r = 0.76***). As this test is much faster to realize than an extensograph, we recommend the sedimentation volume as rapid test for baking quality in spelt. Whether spelt breeding will focus more on quality in future depends mainly on the traders, millers and bakers, which need to clearly define their future quality traits for spelt.

Spelt – a cereal with long tradition in alemannic Europe

Spelt (Triticum aestivum ssp. spelta) has been receiving increased popularity across the last decades. Starting a few decades ago in Baden-Württemberg, south Germany, spelt is now grown not only throughout Germany but also increasingly in other European countries as well as in the USA and Australia. A very rough estimate puts the area under spelt cultivation at > 100,000 hectares in Germany and about the same again outside Germany. Over the entire production chain, this results in an annual market volume of well over one billion €. The reasons for this continuous growth are manifold, the consumer wants diversity, healthy, tasty, traditional and "unchanged" foods and spelt seems to combine all this quite well (Longin and Würschum 2016).

However, the market for spelt is quite different from that of the related common wheat. Common wheat is traded internationally, the individual common wheat varieties are divided into clear quality classes depending on the country, and the trade is oriented either on these variety classifications or much more on the basis of individual quick methods, which are used to try to estimate the baking quality when the grains/flours are received. In the case of common wheat, the protein content in particular is taken, and in the case of more precise analyses, a measure of protein quality, e.g. sedimentation value or extensograph.

In Germany, there has long been a registration test for newly bred spelt varieties, in which the Federal Office of Plant Varieties approves only those varieties to be marketable which, in terms of their overall properties, outperform the existing spelt varieties. However, this assessment focuses almost exclusively on agronomy, because the spelt industry has not yet been able to agree on standardized baking tests for variety description. Since very few years, the sedimentation volume and farinograph values are measured within that testing process but without consequences on the final registration. This lack of quality classification, of course, complicates trade, processing and breeding. Furthermore, experience clearly shows that there are very large quality differences between spelt varieties. We do not want to talk about bad and good here, but there are simply varieties that are more suitable for the special pastry "Seele" and others that are better for the classic pastries.

In order to shed some more light on the baking qualities of spelt and to check whether baking quality can also be estimated by means of faster indirect laboratory methods, we realized a very large spelt trial at the University of Hohenheim together with the private breeding companies Südwestdeutsche Saatzucht GmbH & Co. KG and Pflanzenzucht Oberlimpurg. The extensive baking analyses were made in the Aberham laboratory (http://www.getreidechemie.de/), which was made possible by the generous funding of the University of Hohenheim.

Material & Methods

In many years of work, we have collected seeds of ancient spelt varieties (so-called landraces) from various gene banks, cleaned them up and propagated them. In addition, we have obtained spelt varieties bred in the 70-90s (hereinafter referred to as 1st generation spelt varieties) as well as modern varieties and the latest breeding lines of the few active spelt breeders (modern varieties). In the end, 160 varieties came together, which we then tested in yield trials at the following three locations in 2015: Stuttgart-Hohenheim, Rastatt, Schwäbisch Hall. To improve the accuracy of the trials, some of the varieties were repeated at each location, the specialist calls this p-rep design, so that in the end there were 200 field plots at each location. Since very lodging susceptible old varieties were included, we fertilized only with 70-120 kg of nitrogen, used twice a growth regulator and also applied fungicides. Harvest samples of yield trials were used for quality analyses, but had to be dehulled and cleaned before further quality assessment. In addition to classical traits like protein content (NIRS, ICC standard method 159), wet gluten content (ICC standard method 137/1), sedimentation volume (with sodium dodecyl sulfate; ICC standard method 151), farino- (ICC standard method 115/1), extenso- (ICC standard method 114/1), alveograph (ICC standard method 121) as well as the baking volume were determined using 40ppm ascorbic acid in freely pushed bread rolls (so-called 10-point scheme of the Aberhams baking laboratory). The statistical analysis was made with the software package R using the package ASREML.

Agronomic properties

The modern spelt varieties achieved > 10 dt/ha higher raw yields than the old landraces even under the rather extensive growing conditions. Due to the significantly reduced growth height of the modern varieties, they can of course be grown with even more fertilizer, which increases the yield advantage over the landraces to 20% and more on average - a very relevant difference for the farmer but alos for the supply chain enabling lower prices.

Interestingly, we identified also large differences in raw yield among the landraces. Yields varied from 55 dt/ha for the old landrace Kippenhauser Roter Spelz to 72 dt/ha for the old landrace Kippenhauser Weisser Spelz. The landraces with high yields in particular are very interesting as parents for further spelt breeding.

Beside lower risk to lodging and higher yield, modern spelt varieties were also more resistant against fungal diseases in the field (data not shown), a topic which must receive more interest in spelt breeding due to future restrictions in use of fungicides.

Variation is large across different spelt varieties for baking quality traits

Even though there are significantly fewer varieties of spelt compared to common wheat, these varieties differ considerably in their quality traits. For example, the baking volume varied between 500 and 700 ml (Tab. 1, Fig. 3) and the bread rolls had very different shapes (Fig. 1). The same applies to the dough properties, which ranged from very short dough to well stretchable or even very sticky and flowing doughs. By the way, these quality traits varied not only across spelt varieties but also considerably across the individual test locations, which is well-known from common wheat. In this respect, we want to emphasize that as in common wheat, the description of quality traits of spelt varieties should rely on several kernel samples grown at different field locations.

Due to this variability, a more precise description of the dough and baking properties of spelt varieties is very important so that the miller and baker can select the appropriate varieties for the respective end product, which in turn guarantee a constant and high quality. Thus, it would be desirable if such a description were to be provided centrally, be it at the Federal Office of Plant Varieties or at the state variety trials or elsewhere. This is meanwhile realized in Germany, the Federal Office of Plant Varieties uses since very few years the sedimentation volume and the farinograph in order to describe the quality of spelt varieties in the registration process.

We were also able to identify a few general differences compared to common wheat. For example, water absorption in the farinograph is lower in spelt than in common wheat, which could be an explanation for the phenomenon that spelt breads tend to “be dry” after baking. Spelt doughs also tend to be somewhat more flowing, but can be stabilized by stretch and fold and/or the use of ascorbic acid or acerola cherry juice powder. The protein content varied among the spelt varieties from 12.6 to 17.3% (Table 1), which is considerably higher than for common wheat. Even more, gluten quality differs also to common wheat. Gluten is roughly divided into glutenins and gliadins, both of which represent groups with several subproteins each. In the case of glutenins, spelt lacks the genes/proteins that stand for the best baking quality in wheat. Specifically, these are alleles 7+8 and 7+9 in the glutenin B1 gene (Würschum et al. 2016).

Which indirect methods are suitable for quickly determining the baking quality of spelt?
Ideally, the baking properties of a spelt batch is determined with a baking test, although the question then immediately arises which baking test is best suited for which product range. In this study, we were interested in a standard method that determines the loaf volume and shape stability of a free-baked bread roll in a kind of high throughput measurement system. We followed the Rapid Mix test procedure except that 40 instead of 20 ppm ascorbic acid was used. While this improves the doughs and baking results somewhat, our concern was that we could clearly make visible the differences between the spelt varieties and not run the risk that, in retrospect, they would all have very little loaf volume and be almost indistinguishable in their baking quality. The Aberham baking laboratory has intensively developed this test, which is adapted to spelt, and has been carrying it out successfully for a long time. Furthermore, our results with large genetic variance between the spelt varieties and relatively good environmental stability (high heritability) support the quality of this test (Tab. 1).

However, not every miller, baker, breeder and trader can perform baking tests on every commercial kernel batch. Thus, indirect methods are needed, which ideally achieve results very quickly and on little sample material, which are closely related to the baking result, i.e. having a high positive correlation with loaf volume. In common wheat, the protein content is used first and foremost. In spelt, however, the protein content correlates only very low with the loaf volume (Fig. 2). To illustrate, if an arbitrary limit of 14% protein content is set in Fig. 2, the loaf volumes of the spelt varieties vary between 500 and 700 ml below and above this fictitious limit. The protein content is therefore completely unsuitable for describing the baking quality of a spelt variety! Also, the wet gluten content, which is often considered in the spelt industry, hardly correlated with the baking volume and is therefore also not suitable as a quick method to determine the baking quality of spelt. By the way, protein content correlates very highly with wet gluten content ($r > 0.86$***, data not shown), which is also the case in wheat. In this respect, one can probably save the significantly more complex determination of the wet gluten if the protein content is determined anyway.

The individual analysis values of the farinograph also correlated only weakly with the loaf volume in spelt. While water absorption and dough stability did not correlate at all with baking volume, the highest correlation of all farinograph measurements was found for mixing tolerance index of $r = -0.65$*** (Fig. 3). However, this correlation is significantly lower than for the extensograph (see below) and we therefore consider the farinograph to be less helpful in assessing the baking quality of spelt. Spelt tends to dry baking, but there are varieties that can absorb significantly more water than other spelt varieties. In this respect, one should think about determining the water absorption.

The highest correlation with the loaf volume was achieved by the energy value of the extensograph with $r = 0.86$*** (Fig. 4). This correlation was also very stable in the individual locations and we would like to suggest that this value is the most suitable to estimate the loaf volume of different spelt varieties. We determined this value after 90 minutes of dough proving, but the determination after 135 minutes of dough proving correlated similarly well with the loaf volume. In contrast, the energy value measured on a dough strand that had only 45 minutes of dough proving correlated significantly less with the loaf volume (data not shown).

Outside Germany, the alveograph is often used as an alternative to the extensograph. Very roughly, both are dough stretching tests, whereby the extensograph stretches in only one direction, while the alveograph inflates a piece of dough like a balloon, i.e. a multidimensional stretching is performed. The alveograph also described the baking volume relatively well, the correlation was about r = 0.77*** for the L and G values with loaf volume. Based on our results, however, we would prefer the extensograph.

Applying the extensograph or alveograph, baking is not required, but with both, standardized doughs must first be prepared, and thus both methods are still very time-consuming. This is different with the sedimentation volume, where only floury aqueous solution has to be prepared and plant breeders in particular have developed mini-quick methods that can analyse hundreds of samples a day. In contrast to common wheat, the sedimentation value for spelt is not determined according to Zeleny, but with sodium dodecyl sulfate (ICC 151). The latter differentiates the spelt varieties much better, which has been nicely shown by Rapp et al. (2016), among others. The correlation of the sedimentation volume with the loaf volume was also high with r = 0.76*** (Fig. 5). This is not surprising, since this test also correlates very well with final product quality in durum and common wheat, and older studies also report this from spelt (Schober et al. 2002). Of course, it should be kept in mind that the correlation is 0.1 lower than with the extensograph, but the methodological effort is so much lower that we believe it can be fully justified to present the sedimentation volume as the method of choice to roughly but quickly estimate the loaf volume in spelt varieties.

Can spelt breeding select for quality?

As described above, there are very large differences in the dough and baking properties of spelt varieties. These large differences, which we breeders refer to as genetic variance, would also allow us to select for a specific quality direction. The chances of success of this selection now depend on several things. First, we breeders can only improve traits that depend mainly on the genetics of the variety and less on the environmental conditions at the respective growing location, we breeders are talking here about traits with high heritability. Both loaf volume and numerous dough traits had high heritability in our trial (Tab. 1), which allows efficient selection. Furthermore, in breeding, a large number of candidate varieties, each still grown in several environments, must always be studied in order to make a robust selection decision. In this respect, only traits that can be measured very quickly on as little sample material as possible can be improved. Here, baking tests and dough tests such as farino-, extenso- and alveograph are immediately ruled out, but a sedimentation volume is within the realm of possibility.

The basic prerequisites for quality selection in spelt would therefore be given, but selection for new traits always costs effort and money. It is therefore only worthwhile for a breeder to invest in this if his varieties also gain a market advantage as a result. However, due to the lack of quality classifications in variety testing in spelt and the lack of clear quality market requirements, it is yet difficult to breed for quality. It is therefore urgently necessary that the spelt industry agrees on clear quality criteria and their description. This would not only simplify breeding, but also the entire trade and production chain, because a clear description of the qualities would already be given at the time of variety approval and the industry would not have to work this out independently and laboriously afterwards.

Tips for the baker's practice

For baking practice, some important findings can be derived from our study. Practical experience is confirmed that spelt cannot be processed in the same way as common wheat. If one wants to produce bread or bread rolls with a lot of spelt, the recipe and dough management should definitely be adapted. Compared to common wheat, the main differences of spelt are higher protein content with lower protein quality and lower water absorption of the flour. Thus, kneading energy should be reduced, water uptake of the dough should be increased, e.g. using soakers and/or predoughs/sour-dough, and doughs should be stabilized with several times stretch and fold. Furthermore, product types should be adopted to these specific qualities. Applying these tips, bakers can deliver very aromatic breads with unique characters and shapes.

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Fig. 1: Bread rolls from the standard baking trial of two different spelt varieties grown at the same location. The different baking quality in this example is therefore based on genetics.

Fig. 2: Mean loaf volume in relation to protein content for 160 spelt varieties (averaged over three locations) and Pearson's correlation coefficient r = 0.34.

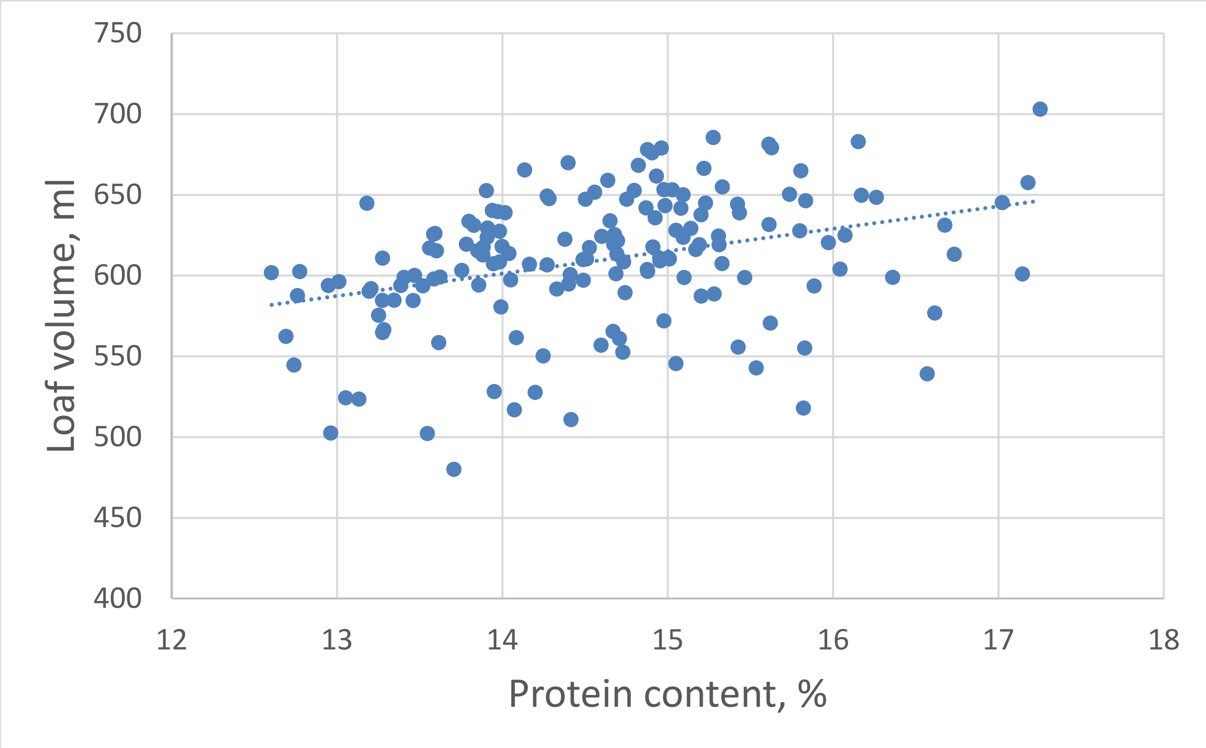

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Fig. 3: Mean loaf volume in relation to mixing tolerance index of the farinograph for 160 spelt varieties (averaged over three locations) and Pearson's correlation coefficient r = -0.65.

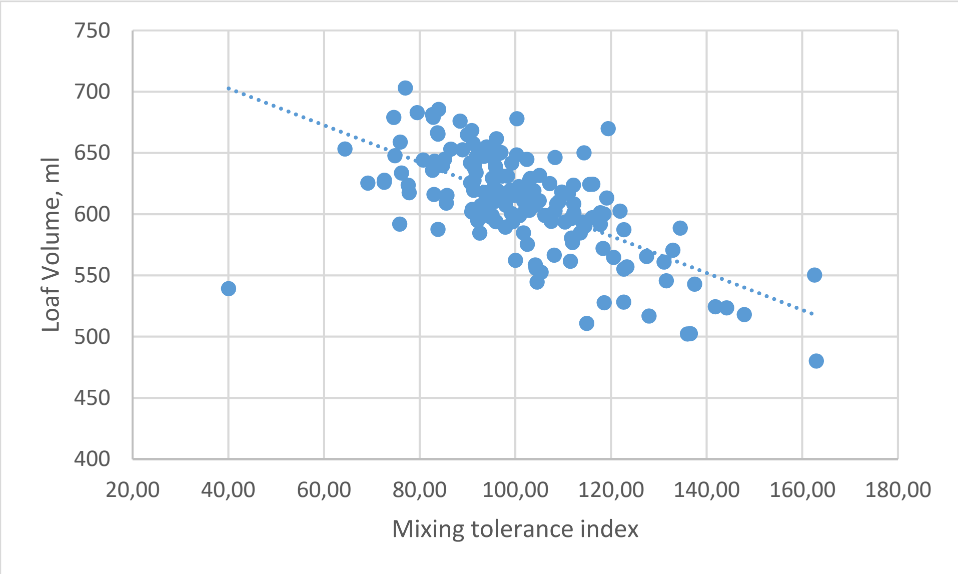


Fig. 4: Mean loaf volume in relation to the energy value of the extensograph after 90 minutes proving time for 160 spelt varieties (averaged over three locations) and Pearson's correlation coefficient r = 0.86.

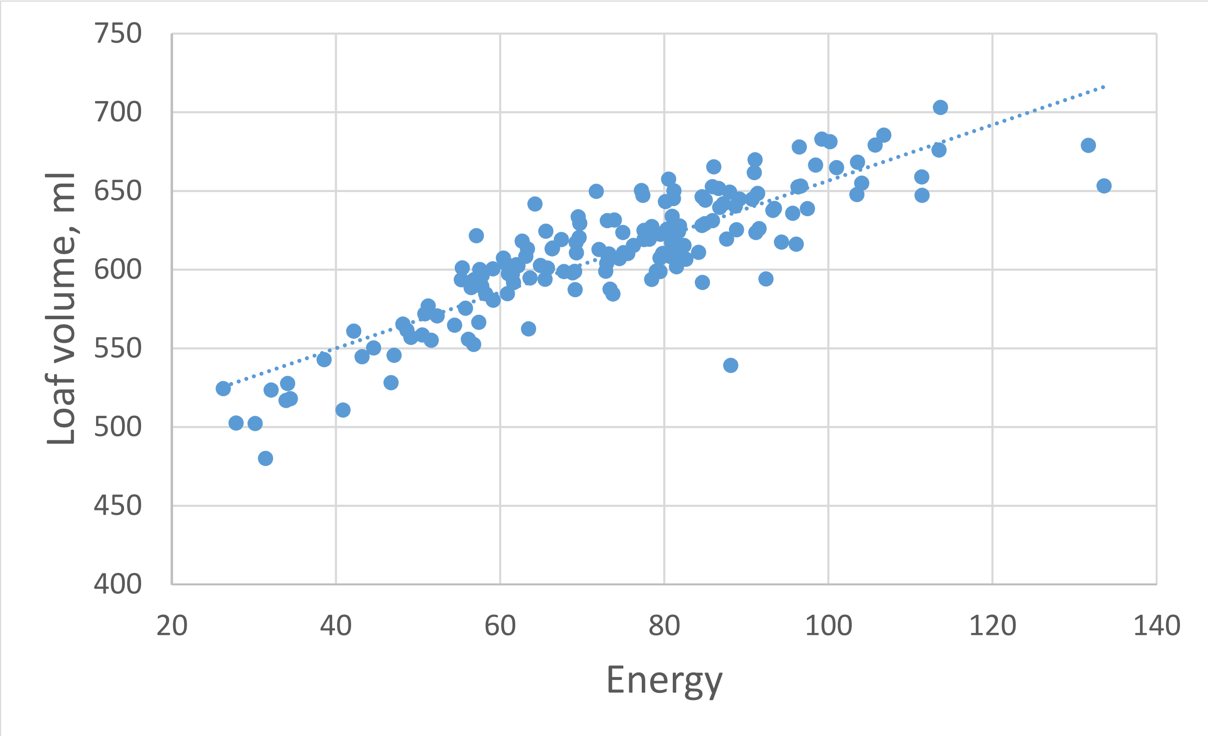
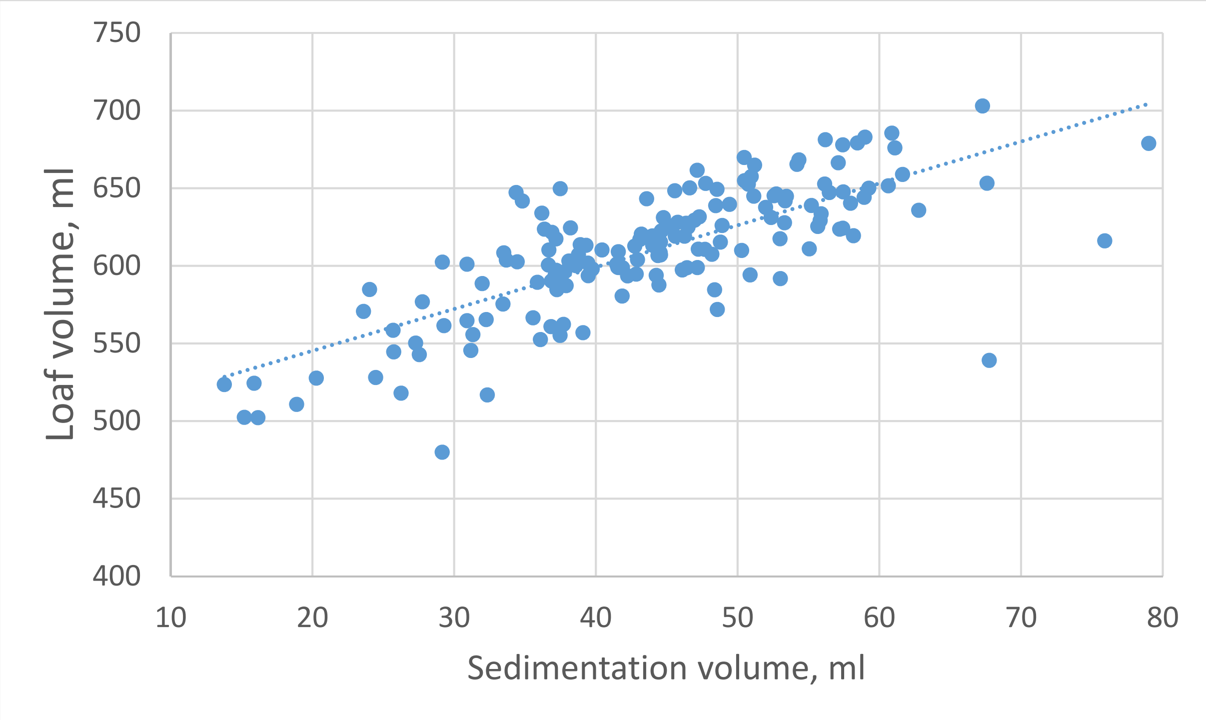


Fig. 5: Mean loaf volume in relation to sedimentation volume for 160 spelt varieties (averaged over three locations) and Pearson's correlation coefficient r = 0.76.



Tab. 1: Variance components (σ^2_G = genetic variance, σ^2_{GxE} = genotype x environment interaction variance, σ^2_e = variance of residual error), heritability (h^2), least significant difference at 5% probability level (LSD), and range of the 160 spelt varieties averaged across three locations (Bauländer Spelz and Oberkulmer are well-known spelt landraces, Franckenkorn and Zollernspelz widely grown modern spelt varieties)

	Raw yield (dt/ha)	Protein content (%)	SDS (ml)	Energy	Loaf volume (ml)
Bauländer Spelz	65.01	14.91	61.11	113.15	675.89
Oberkulmer	65.40	17.02	52.59	81.14	645.04
Franckenkorn	76.17	14.27	48.56	87.98	649.16
Zollernspelz	70.81	15.28	60.90	106.78	685.37
Min	54.49	12.59	13.98	26.29	479.90
Mean	70.52	14.60	43.87	73.56	609.60
Max	81.30	17.27	78.98	133.63	702.90
σ^2_G	16.77***	0.88***	127.68***	365.59***	1422.01***
σ^2_{GxE}	21.52***	0.20***	15.74***	42.62***	0.00
σ^2_e	13.70	0.18	4.85	73.59	950.10
h^2	58.72	0.88	0.95	0.91	0.84
LSD	9.84	1.00	7.44	17.15	46.84

*, **, *** significant at 0,05, 0,01 and 0,001 probability level