

Wheat evolution activities.

Summary

Wheat is a familiar crop and flour is a familiar food (or starting material).

The evolution of wheat from wild grasses demonstrates the dramatic effect of both natural and directed evolution on the structure of a crop plant and the chemical makeup of the product harvested from it.

These activities illustrate the changes to both the structure and the chemistry of the wheat plant.

They include materials that can be printed out for illustrative purposes and practical activities that can be run as demonstrations or hands-on activities.

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Background

Wheat evolution

Wheat is a staple crop for a significant proportion of the world's population. Wheat cultivation occupies more land (240m ha) than any other commercial crop.

Wheat was one of the first crops brought into cultivation. Its domestication began about 10,000 years ago.

Wheat originates from the Fertile Crescent in the Middle East (northern Israel, Lebanon and parts of Iraq and Syria). There is evidence that the wild grasses, which are the ancestors of modern wheat, were collected by hunter gatherers for 1000s of years before they were cultivated.

Wild Emmer wheat (*Triticum dicoccoides*) and, to a lesser extent, wild Einkorn wheat (*Triticum urartu*) were the first cultivated wheat species. Both are wild grasses ($n=7$).

Emmer is a natural hybrid between *T. urartu* and an unidentified goat grass. In the hybrid the 7 chromosomes from each parent spontaneously doubled ($2n = 28$) to give a natural, fertile, interspecies hybrid that is tetraploid.

Emmer was widely grown in the Neolithic period and spread throughout Europe – eventually reaching the UK in about 4,000BC. Domesticated Emmer wheat (*T. dicoccum*) continued to diversify over the centuries; a major development from Emmer was the tetraploid 'durum' wheat (*Triticum durum*).

Meanwhile, in the Middle East, Emmer wheat became the ancestor of bread wheat (*Triticum aestivum*) when it hybridised with a goat grass (*Aegilops squarrosa*) to gain another set of 7 chromosomes. Natural chromosome doubling made the hybrid fertile ($2n = 42$). *A. squarrosa* contributed the genes that produce the glutenin proteins, which account for the elasticity of dough made from *T. aestivum* flour. Bread wheat reached the UK, and replaced Emmer wheat, during the Iron Age (100 – 800BC).

Wild wheats typically have ears that are fragile and shatter once ripe, and glumes that are tightly stuck to the grains. These characteristics make them difficult to harvest and thresh. Domesticated wheats have non-shattering ears and grains that are easier to thresh.

Distinctively, bread wheats produce glutenins in their flour, which, when the flour is kneaded with water, produce an elastic dough that rises well and gives a light loaf with an open structure.

T. aestivum was produced by natural and semi-natural interspecific hybridisations that generated new gene combinations and characteristics that suited wheat to cultivation and processing. Subsequently, ongoing selection and, recently, directed breeding has continued to change the wheat plant.

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The most obvious change in cultivated wheat has been the dramatic reduction in height since the beginning of the 20th century, and especially since the 1960s. By deliberate introduction of a single gene (various alleles of a single gene) it has been possible to produce semi-dwarf wheats that are more resistant to lodging and produce more grain than older varieties. This dwarfing gene was the basis of the green revolution and helped to double wheat yields, worldwide, in the 1960s and 1970s.

There is a diagram of wheat evolution in Appendix 1.

Bread making quality (chemical differences in different wheat, and other, flours)

One of the major concerns for breeders of modern bread wheats is that the wheat flour produces a loaf with the desired physical characteristics. Differences in the nutritional quality of a loaf are almost entirely determined by the processing of the flour into wholemeal or white flour.

The most important physical property of the loaf is its crumb structure. This should be open with plenty of air spaces, otherwise the loaf will have a very dense and chewy texture. For the loaf to have plenty of air spaces the bread dough must be elastic, so that it expands as the fermenting yeast in the dough mix produces carbon dioxide. Crucial to this are the glutenin proteins. These are long flexible protein molecules. During the kneading process these proteins become physically entangled with one another and create an elastic network of protein that helps retain, and is stretched by, the carbon dioxide produced by the yeast.

Different types of wheat, and other, flours have different amounts of, or no, glutenins. These differences can be crudely demonstrated by looking at the kind of dough produced with these flours, how much (if at all) these doughs expand when proved and the structure of the loaves baked from them.

It is possible to wash out the starch and low molecular weight proteins from dough and retain only (mainly) the glutenins – as a gooey lump. The amount of glutenin left, from different flours, indicates the relative ‘strengths’ of the flours.

There is a physico-chemical test (used by breeders and the flour industry) to estimate bread making quality of flour. It uses a weakly acidified, dilute solution of SDS to swell and flocculate the glutenins (and other high molecular weight proteins) in the flour. The more sediment there is after a 5-10 minute sedimentation period – the more proteins there are in the flour and the better the flour will be for bread-making.

Types of flour

‘Strong bread making flour’ from the local supermarket will contain a lot of proteins, mainly gluteins, and should produce a good elastic dough, a reasonably open crumb structure in a loaf, a lot of gluten in a dough-washing experiment and plenty of flocculant in an SDS test.

Other types of flour will vary in their gluten content compared to ‘strong’ flour.

Rye, maize and rice flours contain negligible amounts, if any, of these proteins.

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'00 flour' or 'Italian flour' is durum flour used for making pasta (and bread). This has less protein than strong flour, but still has significant amounts.

Spelt flour should be low in glutens – it does contain other proteins. Spelt flour is typically fortified with bread making flour to improve its bread making qualities.

Soya flour contains no glutenins. It is high in protein and produces a lot of flocculant in an SDS test.

Gluten/Gliadin/Glutenin

Bread making quality of flour is affected by its total protein content, but mainly by the amount of gluten. Gluten is composed of the two proteins gliadin and glutenin. Together these may be 80% of the protein in wheat grains. Glutenin gives dough its elasticity. Gluten forms when wheat dough is kneaded and glutenin and gliadin molecules associate to create an elastic network.

Maize and rice flours lack gliadin. Soya flour is rich in protein, but lacks gluten. None of these 'rise' significantly.

Gluten is also important as a food additive and animal protein substitute. It is common in Asia as Seitan and is used much like Tofu, as a replacement for meat and fish protein.

Dough washing protocol

Summary:

Dough washing removes the starch and water soluble materials from the dough, leaving (mainly) glutenin. The whole process (making dough, resting it and dough washing) is rather long, but can be dramatically shortened by using pre-prepared dough for dough washing.

The appearance of the glutenin from the dough is fascinating and its texture an interesting talking point. Markedly different amounts of glutenin are obtained from different flours.

Timings:

This activity requires a few minutes to make the dough. There is then a rest period of up to an hour. Washing starch from the dough takes about 5 minutes.

To reduce the time required;

- pre-prepared dough could be used for dough washing
- make dough and come back after 30 – 60 minutes
- prepare dough in advance

Age range: Suitable for children over about 10 years old

Process:

1. Mix 250 – 300 g of flour with 150 – 175 ml of water and a teaspoon of salt in a food processor until a soft dough is formed.
2. Wrap in cling film and record its weight.
3. Rest the dough for 60 minutes.
4. Wash over a sieve in several changes of clean water in a large bowl – until the water runs clear.

Prepared glutenin will keep for a few days in a refrigerator.

Table 1. Typical amounts of glutenin obtained from different types of flour:

Flour	Dough weight	Washed weight
Allisons Strong flour	410 g	100 g
Tesco Value plain flour	410 g	90 g
Waitrose spelt flour	410 g	80 g
Alimonti 00 flour	450 g	80 g
Rice flour	420 g	0 g

Doughs made from different types of flour, and the glutenin washed from them, are pictured in Appendix 2.

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Dough rising and baking

Summary:

The amounts, and quality, of proteins in flour determine the extent to which dough will rise. This determines the crumb structure and density of the loaf baked from the dough.

Differences in the rising of dough from different flours can be quite marked and can be accentuated and recorded by 'proving' plugs of dough in measuring cylinders or tubes of baking parchment.

Timings:

Dough can be made in a food processor in less than 5 minutes. Quick start yeast will raise dough (approximately doubling its size) in 30-60 minutes and dough can be 'baked' in a microwave in 5-8 minutes.

The complete process is rather long, but works as a pre-prepared demonstration that is refreshed regularly. Visitors could be invited to set up fresh demonstrations for subsequent visitors and/or to return to see how 'their' dough is progressing.

Age range: Suitable for children over 8 years old.

Process:

1. Mix 250 g flour, $\frac{1}{2}$ tsp salt, $\frac{1}{2}$ tsp sugar, $\frac{1}{2}$ tsp of 'quick start' yeast and 150 – 160 ml of water (at approx 30°C) in food processor, to make soft dough
2. Add more water if necessary
3. Prove the dough in a warm place for 30 – 60 min. Dough from strong bread making flour will about double in size in 60 min. This process is very temperature dependent. In cold venues consider rising dough in a cardboard box kept warm (25°C) with a fan heater.
4. 'Bake' the dough for 5 - 8 minutes in a microwave (6 min in a 650W microwave)

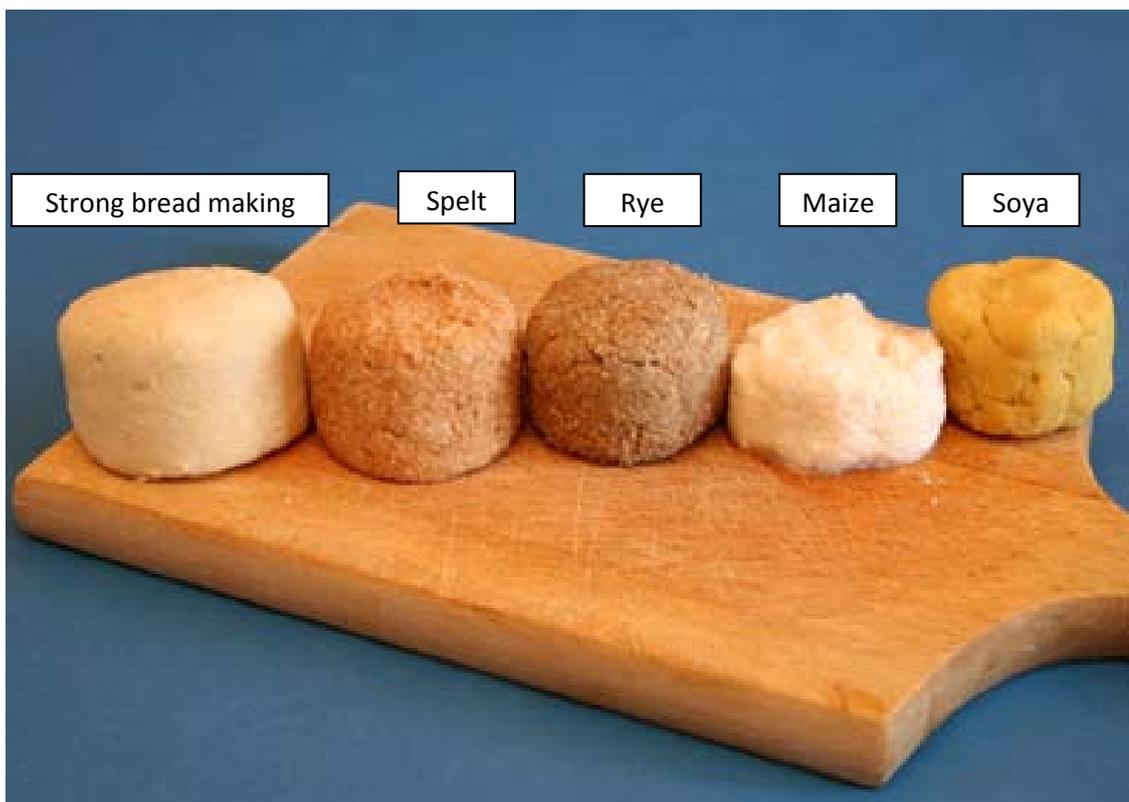
Starting dough, risen dough, 'baked' loaves and loaf crumb structures, from different flours, are pictured in Appendix 3.

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Picture 1. Loaves baked from dough made with different flours. The same weights of flour and water were used and the dough allowed to rise for the same period of time.



Picture 2: Dough plugs. Plugs of similar starting weights, allowed to rise for the same period of time, in baking parchment tubes of similar diameter.



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SDS sedimentation test

Summary:

The SDS sedimentation test is used commercially to predict the bread making quality of flours. The method depends on differences in glutenin swelling, viscosity and sedimentation rates when glutenins interact with water at acid pH. Addition of the ionic detergent SDS increases the electrostatic repulsion, swelling and flocculation of electrically charged glutenins. Most sedimentation occurs within 5 - 10 minutes of mixing the reagents.

Protein content as well as quality affects sedimentation rates. In simple tests both protein content and quality are being measured.

Timings:

It requires about 5 mins to set up 3 or 4 tubes of flour/water ready for the SDS reagent. Flocculant begins to form almost immediately the SDS is added, but tubes need to stand undisturbed for 5 -10 mins for a proper comparison to be made.

Age range: Weighing of flour may be suitable only for older children. Adding and mixing reagents can be done by adults and children over 6-7.

Process:

This is a crude method that eliminates some of the mixing and resting steps of laboratory protocols. SDS/lactic acid should be prepared fresh each day by diluting 85% lactic acid in water (1:8 v/v) and making a 1:48 (v/v) mix of diluted lactic acid with a 2% SDS solution (4 mls to 196 mls).

1. Place 1g of flour in a test tube (preferably 50 ml plastic tube with a screw cap).
2. Add 4 mls of water and mix by shaking vigorously for 10-20 secs.
3. Allow to rest while preparing the other sample tubes.
4. Shake all the tubes again.
5. Add 12 mls of SDS/lactic acid solution to each tube of flour/water.
6. Shake for 10-20 secs.
7. Allow to rest for 2 minutes.
8. Shake for 10–20 secs.
9. Stand tubes for 5 - 10 minutes and then check sedimentation levels.

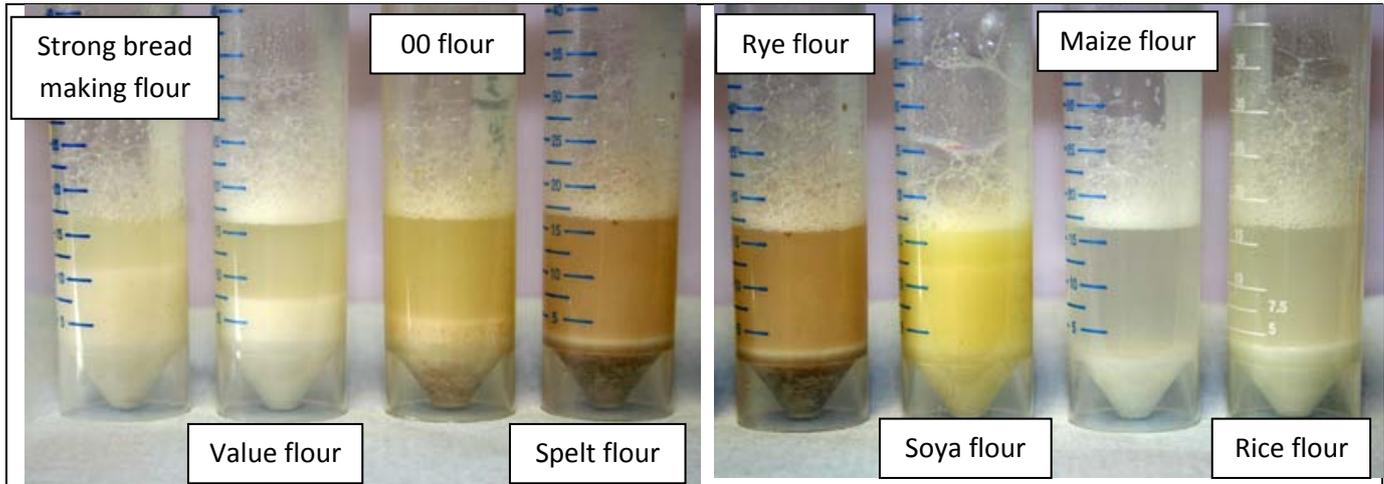
Alternative method using washing up liquid and vinegar:

1. Add 8 mls of water to 2 g of flour in a test tube with a secure lid.
2. Shake well for 10-20 seconds.
3. Once all the tubes are filled, shake them all again.
4. Now dilute washing up liquid (any cheap brand should work) 1:3 with water.
5. Acidify this with vinegar (1:24 v/v) (distilled malt vinegar 5% acidity – any brand should work).
6. Shake all the tubes of flour/water again.
7. Add 24 ml of washing up liquid/vinegar to each tube and shake.
8. When all the tubes have been filled, shake them again.
9. Allow the tube contents to settle and examine the rate and amount of flocculant (5 minutes will be enough for most flocculant to settle).

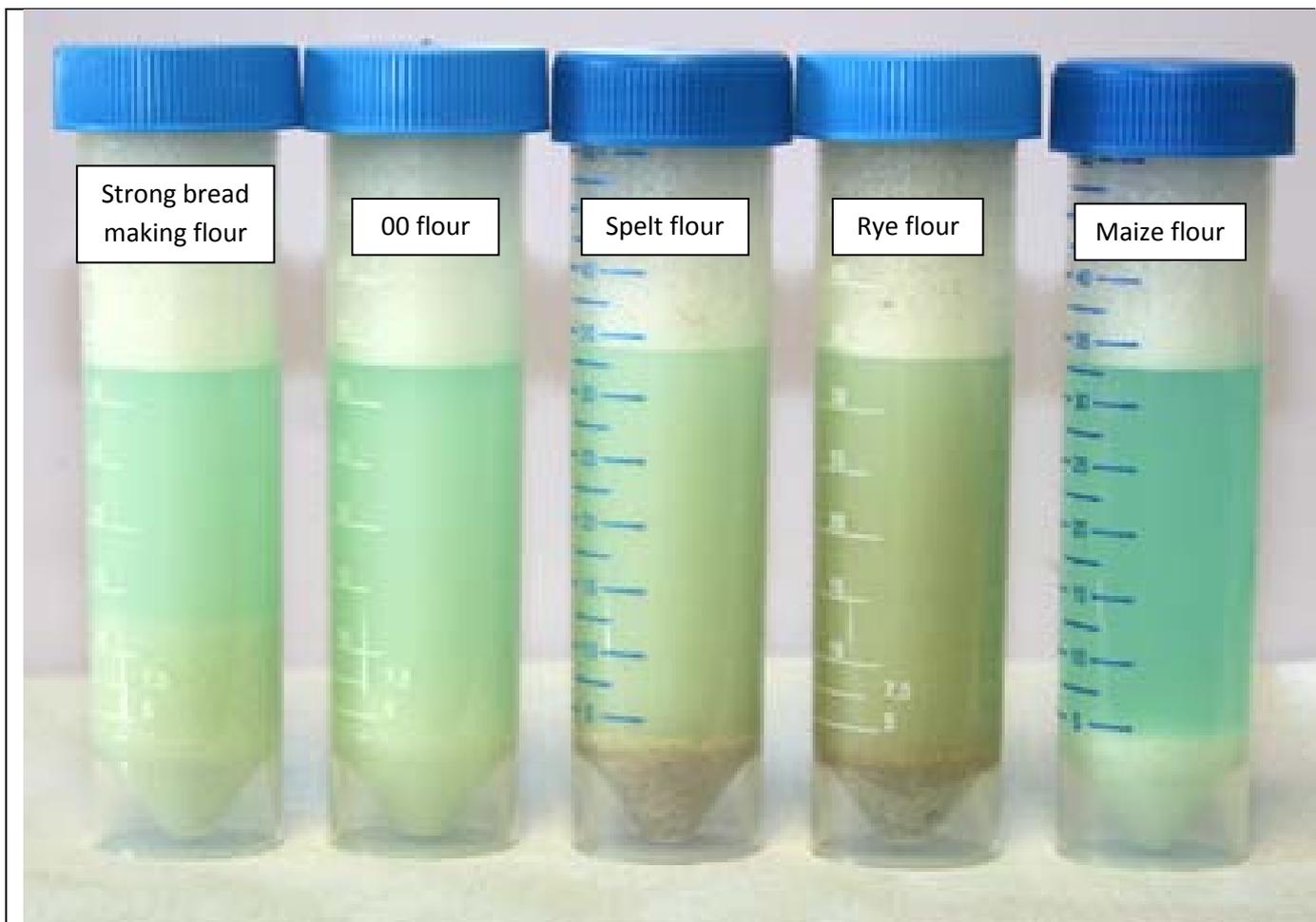
The more flocculant there is, the more protein there is in the flour and the better its bread making quality. Soya flour contains a lot of protein, but no glutenin. It produces a lot of flocculant in an SDS test, but does not make good bread.

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Picture 3. Sedimentation test results – using SDS/lactic acid.

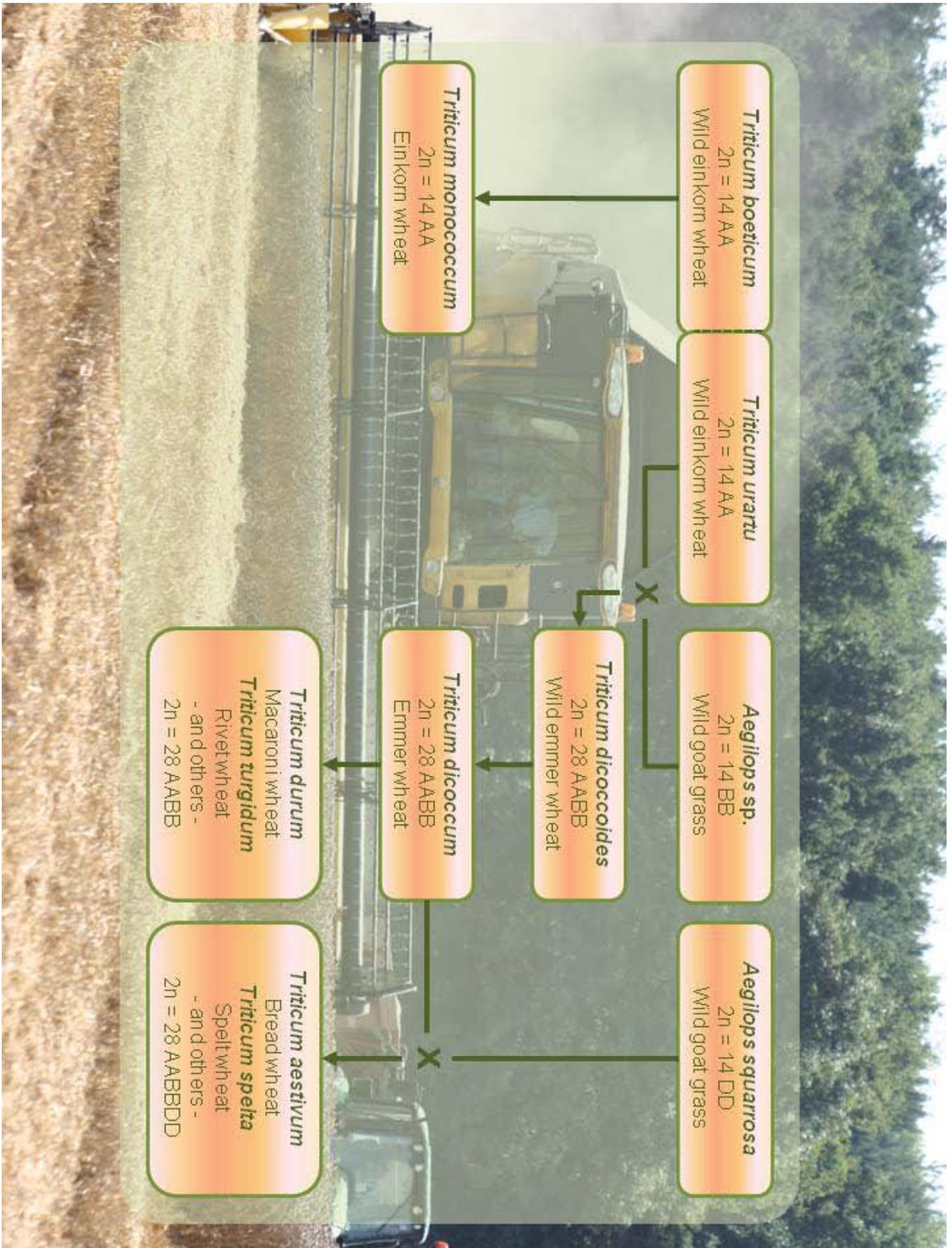


Picture 4. Sedimentation test results using washing up liquid/vinegar.



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Appendix 1.



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Appendix 2.

Dough washing

	Dough pre-washing	Glutenin post-washing
Strong bread making flour		
00 flour		
Spelt flour		

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Rye flour



Nothing left post-washing.

Maize flour



Nothing left post-washing.

Rice flour



Nothing left post-washing.

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Appendix 3.

Dough rising and baking

	Dough	Risen dough
Strong bread making flour		
	Baked loaf	Crumb structure
		
00 Flour	Dough	Risen dough
		
	Baked loaf	Crumb structure

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Dough

Risen dough



Baked loaf

Crumb structure

Spelt flour



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Rye flour	Dough	Risen dough
		
	Baked loaf	Crumb structure
		
Maize flour	Dough	Risen dough
		
	Baked loaf	Crumb structure

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	Dough	Risen dough
Soya flour		
	Baked loaf	Crumb structure
		