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Yield, protein content, bread making quality and market requirements of wheat

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Abstract

In a breeding program with high bread making quality as main breeding goal, different strategies can be used or combined to create genotypes with good bread making quality and improved yield. As protein and yield are negatively correlated, one breeding strategy is to identify genotypes with a deviation to this relationship. Another is to find genotypes with a higher gluten quality to compensate a moderate protein content. Such cultivars with improved yield and very good bread making quality potential are available. As some new bread making processes required more wet gluten than traditionally, some adjustments in the wheat production and in the market are needed. The high bread making potential of new cultivars should not be lost between the breeder and the baker.

Keywords

Bread making quality, HMW-GS, protein content, *Triticum aestivum*, yield

Introduction

High bread making quality is the main goal of the Swiss wheat breeding program (FOSSATI and BRABANT 2003). The quality requirement by the bread making industry is very high and the cultivars have to obtain good to very good bread making quality even in a relatively extensive wheat production. More than 50% of Swiss wheat production do not use any fungicides or straw shortener (so called 'extenso production'). The nitrogen fertilization is relatively moderate, around 140 kg N ha^{-1} are considered as usual amount for winter wheat. Combining yield and high bread making quality in a 'low-input' production is challenging.

Yield versus protein content

As many others breeders we observe the classical negative correlation between protein content and yield. For example, if we summarized all breeding lines and cultivars tested in preliminary and official yield trials between 1987 and 2010 under 'extenso production', the correlation coefficient between yield and protein content is strong and negative (r= -0.60, P<0.01) (*Table1*). The plot shows a kind of barrier under a decreasing curve between yield and protein content (*Figure 1*). Generally, improving yield will lead to a decreased protein content. A breeding strategy could be to identify genotypes with a deviation to the relationship between protein content and yield as proposed by MONAGHAN et al. (2001) or OURY and GRODIN (2007).

Protein content versus other quality tests

Protein content by itself is not sufficient to determine bread making quality. In fact, some correlation between protein content and some bread making quality tests are relatively poor compared to other measurements as Zeleny sedimentation test (ICC Standard Method 116/1) (*Table 1*). When protein quality is more important than protein content, Zeleny sedimentation test gives a better information. For

Table 1: **Correlation coefficients between protein content or Zeleny sedimentation test and different bread making quality parameters for breeding lines and cultivars tested in preliminary and official yield trials between 1987 and 2010 under 'extenso' production**

Quality trait	Protein content (%)	Zeleny sedimentation (ml)	$P>\|r\|$: H_0 r=0	Observations Protein/Zeleny (n)
Zeleny (ml)	0.44	1.00	<0.01	9580
Yield (dt.ha^{-1})	-0.60	-0.23	<0.01	9580/9629
Wet gluten content (%)	0.71	0.32	<0.01	368
Farinograph water absorption (%)	0.40	0.43	<0.01	2048
Farinograph stability time (min)	0.62	0.47	<0.01	2048
Farinograph mixing tolerance index (FU)	-0.31	-0.60	<0.01	2051
Extensograph DL/AL	0.28	0.45	<0.01	2046
RMT bread volume (ml)	0.54	0.14	<0.01	1900
Bread volume in tins (ml)	0.39	0.46	<0.01	288
‚500 g' baking test volume (ml)	0.69	0.36	<0.01	274
Lab tests ‚Schema LP90' (pts)	0.49	0.86	<0.01	317
Baking test ‚Schema LP90' (pts)	0.47	0.51	<0.01	280
Final evaluation ‚Schema LP90' (pts)	0.53	0.75	<0.01	280

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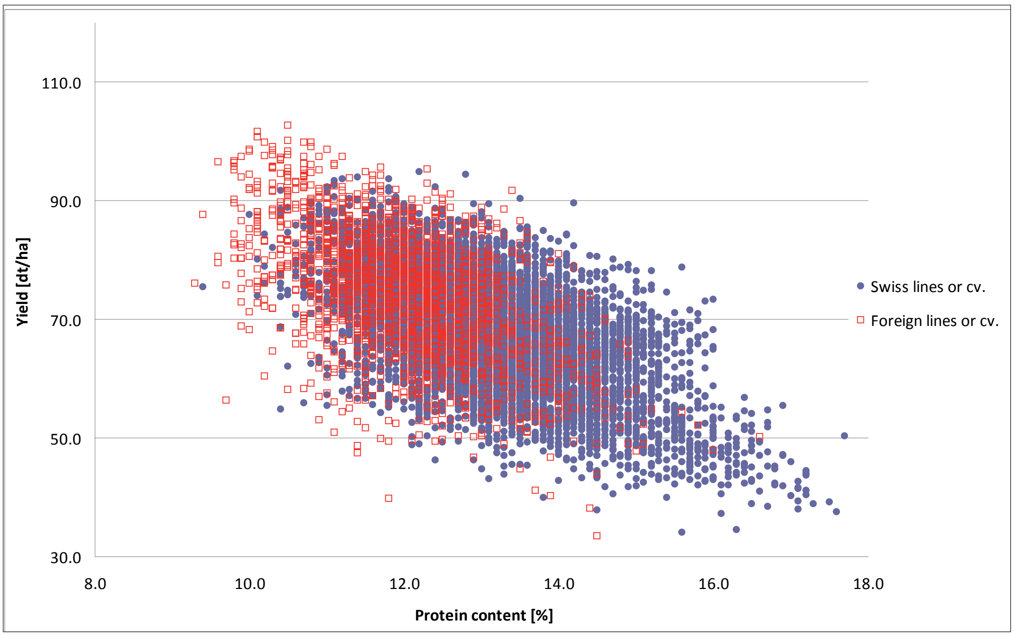

Figure 1: **Relationship between yield and protein content of winter wheat breeding lines and cultivars in preliminary and official yield trials (1987-2010)**

Table 2: **HMW-GS composition of Swiss winter wheat landraces. Quality score (QS) based on quality index according to BRANLARD et al. (1992)**

Local name	Glu-A1	Glu-B1	Glu-D1	QS	Local name	Glu-A1	Glu-B1	Glu-D1	QS
Ausserberg 7D	1	7+8	2+12	40	Liddes	0	7+8	2+12	22
Birgisch	1	7+8	2+12	40	Montana	1	6+8	2+12	24
Birgisch 80D	0	7+8	2+12	22	Muestertal	1	7+8	3 12	42
Bruson	0	7+8	2+12	22	Mund	1	17 18	2+12	40
Casut	1	13+16	2+12	62	Orsières	1	6+8	2+12	24
Chermignon	1	7+8	2+12	40	Orsières	1	7+8	2+12	40
Chermignon 906D	0	14+15	4 12	52	Orsières	2*	6+8	2+12	39
Chermignon 910A	1	7+8	2+12	40	Plantahof	1	6+8	2+12	24
Chermignon 911A	1	17+18	2+12	40	Rothenbrunnen	0	6+8	2+12	9
Erschmatt	1	7+9	5+10	65	Sarrayer	1	6+8	2+12	24
Frauenkirch	1	7+9	5+10	65	Sarrayer	0	6+8	2+12	9
Genève gros	1	6+8	2+12	14	Sarrayer	1	7+8	2+12	40
Guttet	1	17+18	2+12	40	Savièse	1	7+9	2+12	42
Iserables 1145A	0	7	2+12	15	Savièse 847B	1	7	2+12	30
Iserables 1145G	1	7+8	2+12	40	Savièse 852D	1	14+15	2+12	57
Iserables 1147A	0	7+8	2+12	22	Savièse 853A	0	7+8	5+10	45
Iserables 1147D	1	7+9	5+10	65	Savièse 860C	1	7+8	2+12	40
Iserables 1147I	0	7+9	2+12	27	Schmitten	0	6+8	2+12	9
Iserables 77C	1	14+15	2+12	57	Schmitten	0	6+8	5+10	32
La Punt	0	6+8	2+12	9	Surava	1	7+9	5+10	65
Lens	1	7+9	2+12	42	Törbel	1	18+9	2+12	?
Lens	1	14+15	2+12	57	Unter Engadin	1	6+8	5+10	47
Lens 891F	1	7+8/7+9	2+12	41	Visperminen 639D	1	6+8	2+12	24
Lens 892D	0	7	2+12	15	Visperminen 647BD	1	7+9	2+12	42
Lens 892F	1	6+8	2+12	24	Visperterminen	1	7+8	2+12	40
Lens 896E	1	18+9	2+12	?	Vuiteboeuf	1	6+8	2+12	24
Lens 899C	1	7+8	2+12	40					
Lens 899D	1	13+16	2+12	62					

example the Zeleny test has a more consistent relationship with Farinograph mixing tolerance index (ICC Standard Method 115/1), Extensograph resistance to extensibility ratio (ICC Standard Method 114/1), bread volume in tins, points in the laboratory tests or in the global evaluation following the schema '90' (SAURER et al. 1991). Depending on the bread making test, the relationship between protein content and bread volume is more or less consistent. The relationship is good or acceptable with the '500 g' bread making test (KLEIJER 2002) and Rapid-Mix-Test (RMT) (PELSHENKE et al. 1970), but low between protein content and volume of bread produced in tins with a longer fermentation time.

Table 3: **HMW-GS composition of Swiss winter wheat cultivars. Quality score (QS) based on quality index according to BRANLARD et al. (1992)**

Cultivar	Year of release	Secalin	Glu-A1	Glu-B1	Glu-D1	Score *
MC XXII	1913		0	6+8	2+12	9
MC 245	1926		0	7	2+12	15
MC 268	1926		1	6+8	2+12	24
Probus	1948		1	6+8	2+12	24
Zenith	1969		0	7+9	3+12	29
Zenta	1979		0	7+9	4+12	25
Eiger	1980		2*	7+9	4+12	55
Sardonna	1980		2*	7+9	5+10	80
Arina	1981		0	7+8	2+12	22
Bernina[1]	1983	Sec	0	7+8	5+10	27
Forno	1986		0	7+9	5+10	50
Garmil	1987		0	7+8	2+12	22
Ramosa	1989	Sec	1	7+8	5+10	38
Boval	1990		0	6+8	2+12	9
Tamaro	1992		1	7+9	5+10	65
Camino	1993		2*	7	2+12	45
Arbola[1]	1994	Sec	0	6+8	2+12	5
Runal	1995		1	7+9	5+10	65
Titlis	1996		1	7+9	2+12	42
Terza	1996		1	7+8	2+12	40
Levis	1997		1	7+8	5+10	63
Segor	2003		2“	7+8	5+10	78
Arolla	2003		0	7+8	2+12	22
Muveran[1]	2004		1	7+8	2+12	40
Rigi	2004		0	7+8	5+10	45
Piotta	2004		0	7	5+10	38
Zinal	2004		0	7+8	5+10	45
Siala	2005		1	7+8	5+10	63
Fluela	2006		0	7+8	5+10	45
Orzival	2006		0	7+8	2+12	22
Cimetta	2007		2*	7+8	5+10	78
Muretto	2007		1	7+9	5+10	65
Combin	2007		2*	7+8	5+10	78
Logia	2007		2*	7+8	5+10	78
Forel	2007		1	7+9	5+10	65
Mayen	2007		2*	7+9	2+12	57
CH Camedo	2007		1	7+9	5+10	65
Delloro	2007		0	6+8	2+12	9
CH Nara	2008		1	7	5+10	53
Suretta	2008		0	7+8	2+12	22
Dufour	2008		0	7+9	5+10	50
Cambrena[1]	2009		0	7+8	2+12	22
Molinera	2010		1	7+8	5+10	63
Magno	Schedule 2011		1	6+8	5+10	47
Simano			0	7+8	5+10	45
Lorenzo			1	7+8	2+12	40
Campioni			1	7+9	5+10	65
Tanelin			0	6+8	5+10	32

[1] for biscuit production

As correlations between protein content and bread making quality are relatively weak, another possible strategy is to select the genotype with relatively low protein content but high bread making quality.

Using specific HMW-GS for quality improvement

A cultivar can reach a good bread making quality, even with a moderate protein content, if the protein quality is very good. In fact, in many breeding programs, consciously or not, some high molecular weight glutenin subunits (HMW-GS), in particular the 5+10 (*Glu-D1d* allele) giving a stronger gluten, was frequently used for increasing quality and allowing a simultaneous progress in yield. In Swiss landraces, HMW-GS 5+10 was at a low frequency, around 10% in a random sampling of landraces conserved by the national gene bank at Agroscope ACW (*Table 2*). In the Swiss winter wheat cultivars registered from 1900 onwards, the frequency is around 35% and is clearly increasing (*Table 3*).

End users requirements

Using both strategies, new cultivars have been produced, e.g. Molinera, CH Nara, CH Claro, Siala, Camedo or Loren-

Table 4: **Quality results of recently developed cultivars compared to Runal in the Swissgranum[1] trials network and in the official trials network (2008-2010) (Performance better than Runal is printed in bold)**

Trial network	Cultivar	Wet gluten (%)			Laboratory tests (pts)			Baking tests (pts)			Total (pts)		
		2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
Swissgranum	Runal	33.8	31.0	41.2	78	72	79	81	75	66	159	147	145
	Camedo	30.6	30.6	36.1	65	**76**	**81**	64	69	**80**	129	145	**161**
	CH Claro	28.7	**31.9**	35.1	61	67	**72**	**84**	**80**	**89**	145	**147**	**161**
	Nara	32.3	**31.3**	33.8	**82**	**77**	**82**	71	63	**82**	153	140	**164**
	Siala	28.5	30.8	37.3	63	**74**	**72**	70	**77**	**86**	133	**151**	**158**
Official yield trials	Runal	31.1	31.1	34.0	83	83		78	55		161	138	
	Lorenzo		**33.2**	**34.9**		**88**			**59**			**147**	
	Molinera	30.7	30.2	**35.5**	77	**84**		**85**	**77**		**162**	**161**	
	Siala	27.5	29.7		74	79		75	**60**		149	**139**	

[1] Swissgranum is the interprofessional organization for cereals, oilseeds and legumes crops

zo and represent already a significant part of the production. The results of their bread making tests are frequently better then the Top quality standard cultivar Runal (*Table 4*). Even with a large part (83%) of the Swiss wheat production based on good (47.2%, quality class 1) and very good (35.8%, quality class Top) bread making quality cultivars, some end-users are not completely satisfied with the harvested quality. The wet gluten content was considered as insufficient for some processes. Up to 2% dry gluten needed to be added to the flour for some productions.

Some hypotheses, for each step between the producer and the end-user, can explain this situation. Inside both quality classes Top and 1, some cultivars with high wet gluten content, have been less produced than others with less wet gluten content but higher yield potential. The trend of reducing fertilizers use and some years with unfavorable climatic conditions for protein content could be also partially responsible. After harvest, for the same quality class, different cultivars are frequently mixed into the same silo, without a protein content management. Some new bread making processes especially when using fermentation under cold control or a freezing period, need more protein content to be successful. *Arvalis-Institut du végétal* indicates that, if 9-10% flour protein content is sufficient for a traditionally French bread, 11-13% are needed for a normal bread with crude freeze dough or even more than 15% for a normal bread produced with a fermented freeze dough (cited by SEYSEN-FOUAN 2010). Such processes are now common for the bread making industry.

Conclusion

New cultivars with improved yield and very good bread making quality potential are available. This quality is mainly based on very good gluten quality and less frequently on high wet gluten content. Even if some new cultivars have very good results in traditionally bread making tests they can fail to satisfy the requirements of high protein content demanding processes. For such processes, some production and market adjustments are needed to be sure that the potential quality is obtained and reach the end users.

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