Faults in feeds and mills

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Mängel bei Futtermitteln und Mischwerken

1. Introduction

Diet formulation demands great skill and knowledge of animal nutrition (CHOW et al., 1978; CHURCH and VALERA-ALVAREZ, 1991). A nutritionally balanced feed mixture is necessary for optimal growth and wellbeing of farmed animals, for the environment and for the quality (HALE and THEURER, 1972; KHAN, 1997) of the finished products for human consumption. It is therefore important that the technical, hygienic and nutritional standards of the feed mixtures are high.

Production of, and international trading with feed mixtures for livestock is a growing discipline (NAMUR et al., 1988). Most countries, for these reasons, have legislation as to composition and production of feed mixtures for farmed animals (CHURCH, 1991; FAWCETT and WEBSTER, 1991; WILLIAMS, 1995).

Feed mixtures in Norway can be made by any factory with a license. The nutritional content of a mixture has to be guaranteed within an upper and a lower limit. Supervision is carried out by National Agricultural Inspection Service. All compound feed production is systematically sampled and analysed for the most common feed parameters (HARDY, 1989). Biannually the analysed levels and their corresponding guarantee in the samples are given in reports from the Inspection Service.

Many countries have supervising systems, public or private, compulsory or voluntary, of their feed mixing pro-

Zusammenfassung

Untersucht werden Diskrepanzen zwischen analysierten (a) und garantierten (g) Rohproteingehalten (CP) in norwegischen Futtermischungen gab eine signifikante ($p < 0{,}001$) inverse Beziehung zwischen dem Verhältnis a/g und dem garantierten Rohproteingehalt (10 %–45 %) bei 3963 Proben von 17 Mischfutterwerken aus einem Zeitraum von 3 1/2 Jahren. 2,12 % der Proben hatten CP-Gehalte außerhalb der gesetzlichen Streubreite. 19 % dieser mangelhaften Proben enthielten zu viel CP, 81 % zu wenig. Die Regression zwischen Fehlerhäufigkeit (fT) und gCP: $fT = -3{,}55 + 0{,}36 \times gCP$ war hoch signifikant ($p = 0{,}015$) Die Gesamtfehlerhäufigkeit fiel während des Untersuchungszeitraumes von mehr als 3 % auf weniger als 1 % ($p = 0.034$). Es gab keinen signifikanten linearen Zusammenhang zwischen der Mängelhäufigkeit und der Lage der Mischfutterwerke in sechs landwirtschaftlichen Produktionsgebieten.

Schlagworte: Protein, Futtermischungen, Tierhaltung, Qualität, Diskrepanzen.

Summary

Discrepancies between analysed (a) and guaranteed (g) crude protein (CP) in Norwegian feed mixes were studied. There was a significant ($p < 0.001$) inverse relationship between the ratio a/g and gCP (10 %–45 %) in 3963 samples from 17 mills during 3.5 years. 2.12 % of the samples had CP content outside the statutory range. 19 % of these faulty samples had CP in excess, 81 % were deficient. Fault frequency (fT) regressed versus gCP: $fT = -3.55 + 0.36 \times gCP$; was highly significant ($p = 0.015$). The total frequency of faults dropped from more than 3 % to less than 1 % during the surveyed period ($p = 0.034$). There was no significant ($p = 0.936$) linear relationship between the frequency of faults and localisation of the mills in six agricultural efficiency zones.

Key words: protein, feed mixes, farmed animals, quality, discrepancies.

duction. A description of practice in USA, the Netherlands, France, Denmark and Germany is given by ANONYMOUS (1998) and shows that still little is published on accuracy and precision in this industry. Supervision by the Dutch system in 1996 showed that 3.5 % of the crude protein (CP) samples fell outside the EU tolerance. For the mills comprising "Korn – og Foderstof Kompagniet" in Denmark the third quarter figures for 1997 showed that only 0.6 % of the samples were outside the tolerances. SOEVIK (1998) showed that eleven factories in Western Norway over a period of eight years under a supervising system with tolerances more narrow than in the EU system had a total fault frequency that depended on the CP level in the mixes and could be described by the equation:

fT = -1.77 + 0.68 X gCP %. 94 % of the faulty samples were deficient in CP and 6 % had CP in excess.

The present work concerns feed mixes from the 17 largest mills in Norway. The supervising system is as practised in EU (WILLIAMS, 1995). The sampled period was 3.5 years. The relationship between analysed and guaranteed CP categorised by CP level, by year and by factory will be looked at.

The transport expences were subsidized so there should be no differences in price between the factories; the competition was on quality and service only.

2. Factories, sampling and analysis

2.1 Feed mills

This study concerns those 17 mills (coded F1–F17) in Norway producing more than about 30,000 tonnes feed mixture yearly. Figure 3 is showing the code for the mills and their localisation in agricultural efficiency zones according to legal regulation for productional support for farmers (LANDBRUKSDEPARTEMENTET, 1996). Zone 1–6 is mainly in the south-north direction. The most efficient, zone 1, has the lowest support and the best agricultural conditions.

2.2 Feeds and mixtures

The mixtures were for ruminants, pigs and poultry and compounded with levels of CP mainly between 10 % and 40 %.

2.3 Sampling of feedstuffs and mixtures

Every sample is representing about 1000 tonnes of a feed mix.

The sampling, marking and handling procedures were set by the Ministry of Agriculture and were in accordance with EU practice for trade in cereals and feedstuffs (WILLIAMS, 1995). The samples were sent to National Agricultural Inspection Service, Laboratory of Agricultural Chemistry for chemical analysis. When the chemical contents of mixtures were found to be outside the statutory limits, the mixtures had to be adjusted promptly to comply with the formula. The values obtained over a period of some weeks were required to have an average as guaranteed.

2.4 Analysis

The CP level in every mixture has to be guaranteed by a fixed value. A deviation by chemical analysis could be tolerated, but a deficiency or an excess had to be within statutory ranges. According to EU regulations (WILLIAMS, 1995), CP tolerances vary depending on the level in the mixes. For mixtures with less than 10 % CP the range is from one unit below to two units above. Between 10–20 % there is a 10 % margin below and a 20 % margin above. For levels over 20 % it´s two units below and four units above.

The statutory coefficient of variation is accordingly more benefitial for mixes having declarations of CP less than 10 % than for mixes having declarations of CP higher than 20 %.

The samples were analysed for CP, by the method of Kjeldahl (% N X 6.25). The results are published by Agricultural Inspection Service (1995–1998) in reports twice a year since 1995. The present study is based on data from seven successive reports (hY1–hY7).

2.5 Statistical analysis

The collected data were treated statistically in accordance with recognized methods (SNEDECOR and COCHRAN, 1974) and carried out using the Systat software (SYSTAT, 1992a; b).

For each sample the ratio between analysed CP (a) and guaranteed CP (g) was calculated (a/g). The average values for the mills are shown as are the number of samples taken (nS). When calculating the regression of (a/g) on (g) the corresponding slope (b) was found and tabulated.

Faulty samples could be deficient in CP (nD) or they could have CP in excess (nE). The number of faulty samples, nT, was the sum of nE and nD. The frequency of faults (fT) was calculated from the expression: nT X 100 % / nS.

3. Results and discussion

3.1 Faults vs. guarantee

When regressing the ratio a/g versus gCP for all samples, the regression was negatively sloped ($b = -0.002$, $p < 0.001$). This means that the ratio a/g was higher in samples from low CP mixtures than in samples from more concentrated mixtures. The samples had, however, on average higher analysed CP content than guaranteed. This is shown in Figure 1.

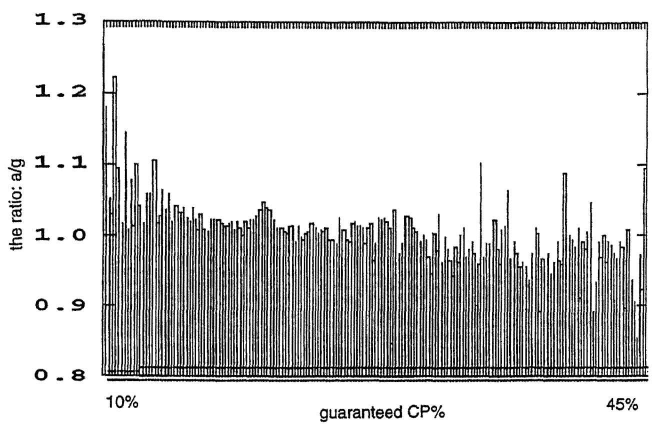

Figure 1: The ratio (a/g) between analysed CP (a) and guaranteed CP (g) plotted versus guaranteed CP (10 %-45 %) in 3963 samples of feed mixes produced by 17 mills during 3.5 years

Abbildung 1: Das Verhältnis (a/g) zwischen analysiertem CP (a) und garantiertem CP (g) aufgetragen gegen das garantierte CP (10–45 %) in 3963 Mischfutterproben von 17 Mischfutterwerken aus 3 1/2Jahren

84 of totally 3963 samples or 2.12 %, had analysed CP content outside the statutory range. The distribution of these faults is shown in Figure 2 and will be further discussed.

The distribution of faulty samples has previously been found to depend on the CP level in the mixtures and could be described by the equation (SOEVIK, 1998):

$$fT = -1.77 + 0.68 \times gCP \% \quad (1)$$

From Table 1, it can be shown that the highest CP levelled

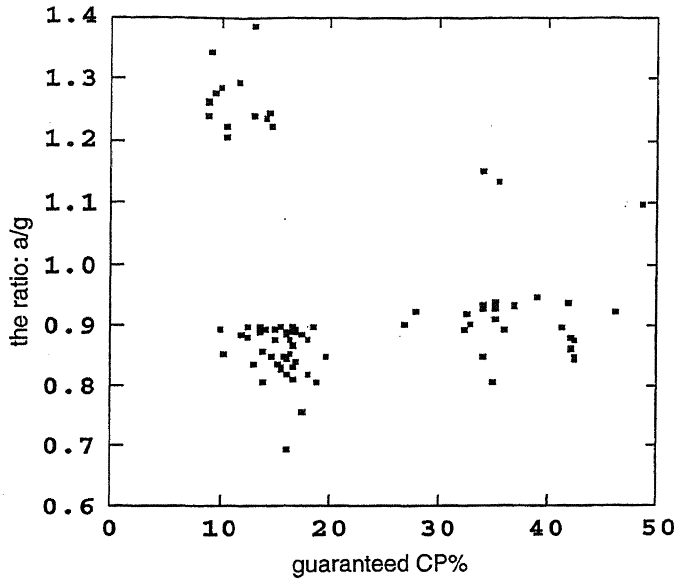

Figure 2: The ratio (a/g) between analysed CP (a) and guaranteed CP (g) plotted versus guaranteed CP in 84 faulty samples (See text for definition of faulty sample)

Abbildung 2: Das Verhältnis (a/g) zwischen analysiertem CP (a) und garantiertem CP (g) aufgetragen gegen das garantierte CP in 84 mangelhaften Proben

mixtures have the highest fault frequencies. Fault frequency regressed versus gCP is highly significant ($p = 0.015$). If the highest level was excluded, then the linear regression was still significant ($p = 0.045$). If the two highest levels were excluded as outliers or of less importance, then the relationship between fT and CP could be written:

$$fT = -3.55 + 0.36 \times gCP, \ (r^2 = 0.481, p = 0.084) \quad (2)$$

Though the linearity is not on an acceptable level of significance the equation fits well, and shows zero faults when CP is slightly below 10%. It also shows that the slope of the line is about half as steep as in (1). This could be due to a general improvement in the industry or that the tolerance ranges have been widened in the EU adopted regime. The latter seems more reasonable.

The most frequently produced mixtures had CP levels between 10 and 20 % and for these mixtures the fault frequency on average ranged from 1.3–1.7 %. Previously (SOEVIK, 1997), it was found that the statutory coefficient of variation (CV) was higher with low CP levels, and lowest for the highest CP levels. There was a high correlation between the frequency of faults and CV.

In Table 2 is shown the distribution of the faulty samples from mixes with CP levels between 10 and 20 % where CV was constant.

Table 1: CP intervals in the mixes. Number of samples (nS), number of faulty samples (nT) that could be excessive (nE) or deficient (nD), and their frequencies (f).

Tabelle 1: CP Klassen in den Futtermischungen. Probenzahl (nS), Zahl mangelhafter Proben (nT) mit Gehaltsüberschreitung (nE) oder -unterschreitung (nD) und deren relative Häufigkeit (f)

CP %	-10	10.1-15	15.1-20	20.1-25	25.1-30	30.1-35	35.1-40	40.1-45	45.1-
nS	90	1885	1748	54	47	80	44	13	2
nT	5	24	29	0	2	8	7	7	2
nE	5	8	0	0	0	1	1	0	1
nD	0	16	29	0	2	7	6	7	1
fT %	5.6	1.3	1.7	0.0	4.3	10.0	15.9	53.8	100.0
fE %	100.0	33.3	0.0	0.0	0.0	12.5	14.3	0.0	50.0
fD %	0.0	66.7	100.0	0.0	100	87.5	85.7	100.0	50.0

Three things can be seen from this:

1. the faults become more deficient with increasing CP level.
2. the frequency of faults was not significantly correlated to CP level ($p > 0.05$)
3. the frequency of faults had its lowest value of about 1 % in the most frequently produced mixtures (having CP levels between 14 % and 16 %). Mixes in the other CP categories were more faulty.

Table 2: CP intervals in the most produced mixes. Number of samples (nS), number of faulty samples (nT) that could be excessive (nE) or deficient (nD), and their frequencies (f)

Tabelle 2: CP Klassen in den gebräuchlichsten Futtermischungen. Probenzahl (nS), Zahl mangelhafter Proben (nT) mit Gehaltsüberschreitung (nE) oder -unterschreitung (nD) und deren relative Häufigkeit (f)

CP%	10.1-12	12.1-14	14.1-16	16.1-18	18.1-20
nS	357	965	1344	756	211
nT	7	12	14	17	3
nE	3	3	2	0	0
nD	4	9	12	17	3
fT %	1.96	1.24	1.04	2.25	1.42
fE %	42.9	25.0	14.3	0.0	0.0
fD %	57.1	75.0	85.7	100.0	100.0

From Table 1 it can be shown that 16 faulty samples had excessive CP content (19 %), while 68 were deficient in CP (81 %). The deficiency is somewhat less than those 94 % reported previously (SOEVIK, 1998), but means at the same time that the percentage of excessive faulty samples has more than tripled, from 6 % (SOEVIK, 1998) to 19 % found here. This is probably a result of wider and asymmetrical statutory tolerance ranges and limits under the EU adopted system.

3.2 Faults vs. time

Table 3 shows that the sampling frequency increased from 440 the first six months to 634 the sixth half-year and dropped to 566 the last half-year. The frequency of excessive faulty samples was rather steady with values less than 1%, while the frequency of deficient samples decreased. The excessive fraction of the faults (fE), however, varied roughly between 5 % and 35 %, while the deficient fraction (fD), varied roughly between 95 % and 65 %. Calculated regressions for fD and fE versus time, however, were not significantly linear ($p > 0.05$), though both showed inverse relationships versus time. A t-test of the mean values showed, fD > fE ($p = 0.032$).

The frequency of total faults regressed versus time (in half-years), however, showed an inverse relationship:

$$fT = 3.080 - 0.323 \times hY; \; (r^2 = 0.626 \; p = 0.034). \qquad (3)$$

Table 3: The ratio (a/g) between analysed CP (a) and guaranteed CP (g) for the samples in the six months periods (hY). Number of samples (nS), number of faulty samples (nT) that could be excessive (nE) or deficient (nD) and their frequencies (f).

Tabelle 3: Das Verhältnis (a/g) zwischen analysiertem CP (a) und garantiertem CP (g) für die Proben in den Halbjahresperioden (hY). Probenzahl (nS), Zahl mangelhafter Proben (nT) mit Gehaltsüberschreitung (nE) oder -unterschreitung (nD) und deren relative Häufigkeit (f)

hY	1	2	3	4	5	6	7
nS	440	520	562	610	631	634	566
nT	9	16	19	14	9	9	8
nE	2	2	1	5	1	2	3
nD	7	14	18	9	8	7	5
fT %	2.05	3.08	3.38	2.30	1.43	1.42	1.41
fE %	22.2	12.5	5.3	35.7	11.1	22.2	37.5
fD %	77.8	87.5	94.7	64.3	88.9	77.8	62.5
a/g	1.019	1.005	1.017	1.015	0.998	1.025	1.022

The overall fault frequency dropped from more than 3 % to less than 1 % from the first to the end of the seventh period. The regression was significant, which means that there has been a true reduction in the frequency of faults during the surveyed years.

In Table 4 is shown for each period the number of samples and the number of faulty samples for the most produced CP category of mixtures. The calculated frequency of faults regressed versus time showed the relationship:

$$fT = 2.301 - 0.296 \text{ X hY}; (r^2 = 0.771, p = 0.009). \quad (4)$$

Table 4: Samples from mixes with guaranteed CP from 14.1% to 16.0% collected in six months periods (hY). Number of samples (nS), number of faulty samples (nT) and their frequencies (f).

Tabelle 4: Nach Halbjahresperioden (hY) zusammengefaßte Proben von Futtermischungen mit garantiertem CP-Gehalt zwischen 14,1 und 16 %. Probenzahl (nS), Zahl mangelhafter Proben (nT) und deren relative Häufigkeit (f)

hY	1	2	3	4	5	6	7
nS	180	182	199	216	204	173	190
nT	4	2	2	2	3	1	0
fT %	2.22	1.62	1.01	0.93	1.47	0.58	0.0

The industry has therefore improved significantly these years. This holds for all mixtures, the most frequently produced included. This is contrary to previous findings (SOEVIK, 1998), but confirms the impression from a later investigation (SOEVIK, 1999 unpublished) that the industry has improved during the last years.

In 1997 the fault frequency in mixes reported from Holland was 3.5 %; while for mills in Denmark it was 0.6 % (ANONYMOUS, 1998). The CP range was not given, and as shown above, the CP level is of great importance as to fault frequency in feed mixtures.

The ratio a/g (Table 3) for all mills in each period regressed versus time showed a slight positive slope (b = 0.001) though not significant (p = 0.603). This shows a tendency towards more CP than guaranteed in the mixes with time. Except for the fifth value, the others were larger than 1.0. The mills have therefore mixed to levels better than the guaranteed ones and have these years more and more favoured the customers in accordance with the conclusion from a survey carried out by the UK ministry of Agriculture referred to by ALDERMAN (1985). This is, however, contrary to previous findings by SOEVIK (1998), who only found improvement with time for the most frequently produced mixes.

3.3 Faults vs. localization

The sum of samples taken from the mills in every zone is shown in Table 5. The number of samples decreased with zone number though the relationship was not linearly significant (p = 0.245). The number of factories was with increasing zone number: 4, 1, 2, 4, 4 and 2. This means that on average 243, 794, 162, 221, 193 and 109 samples were taken from each factory in zone 1 to zone 6.

Table 5: Agricultural efficiency zone 1–6. Number of samples (nS), number of faulty samples (nT) that could be excessive (nE) or deficient (nD) and their frequencies (f). The ratio (a/g) between analysed CP (a) and guaranteed CP (g) for the samples in the zones is also tabulated. b (x 10^{-3}) is the slope of the regression a/g versus g.

Tabelle 5: Das Verhältnis (a/g) zwischen analysiertem CP (a) und garantiertem CP (g) für die Proben nach landwirtschaftlichen Produktionsgebieten. Probenzahl (nS), Zahl mangelhafter Proben (nT) mit Gehaltsüberschreitung (nE) oder -unterschreitung (nD) und deren relative Häufigkeit (f)

Zone	1	2	3	4	5	6
nS	972	794	324	885	770	218
nT	15	15	10	19	23	2
nE	2	4	2	2	5	1
nD	13	11	8	17	18	1
fT %	1.54	1.89	3.01	2.15	2.99	0.92
fE %	13.3	26.7	20.0	10.5	21.7	50.0
fD %	86.7	73.3	80.0	89.5	78.3	50.0
a/g	1.012	1.017	1.009	1.008	1.017	1.022
b	-3.5	-1.8	-3.0	-5.2	-6.7	-7.5

The number of faulty samples ranged from 2 in zone 6 to 23 in zone 5. The faulty samples in percent ranged from 0.9 % in zone 6 to 3.0 in zone 3. When bearing in mind that on average one sample was taken for each 1000 tonne produced there were produced 109000 tonnes in zone 6 and about one third of this in zone 3, for each faulty tonne, or sample.

There was no significant (p = 0.936) linear relationship between the frequency of faults and zone number. Neither could the average sample number from the mills in each zone be significantly regressed to zone number (p = 0.245) but the regression was negatively sloped. This means that the mills became apparently smaller in the south north direction.

Most of the faulty samples were deficient in CP. This holds in all zones. Except for zone 6 where one sample was excessive and one was deficient, no significant differences or trends could be found.

The ratio a/g for all factories is shown in Figure 3. Factory F-7 had a ratio slightly above 0.99 while all the others had ratios above 1.0. The ratio shows a slight increase with high zone numbers (Table 5), but because the values for zone 3 and 4 are low the regression was not linear on an acceptable level ($p = 0.331$). The factories 2, 6, 8 and 15 (Figure 3) seem from this to produce the CP richest mixes as to guarantee level. The factories are sited in the zones 6, 4, 5 and 3, respectively.

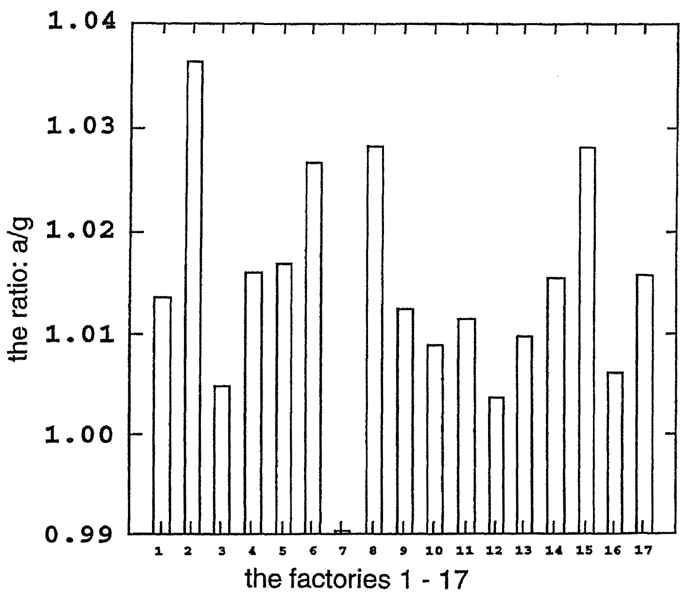

Figure 3: The ratio (a/g) between analysed CP (a) and guaranteed CP (g) in 3963 samples taken from 17 mills during 3.5 years

Abbildung 3: Das Verhältnis (a/g) zwischen analysiertem CP (a) und garantiertem CP (g) in 3963 Proben nach Mischfutterwerken differenziert

levels, the a/g > 1.0 faulty samples (predominantly up to the left in Figure 2) are more frequently from the northern regions. It is therefore the higher frequency of excessive faults in low CP mixes from mills in high numbered zones that are the reason for the inverse relationship above. As there was a tendency towards smaller mills in the north, and as smaller mills are making smaller quanta of each mixture the predominance of excessive faults in the low CP mixes could be due to carry over from the other and more concentrated mixes.

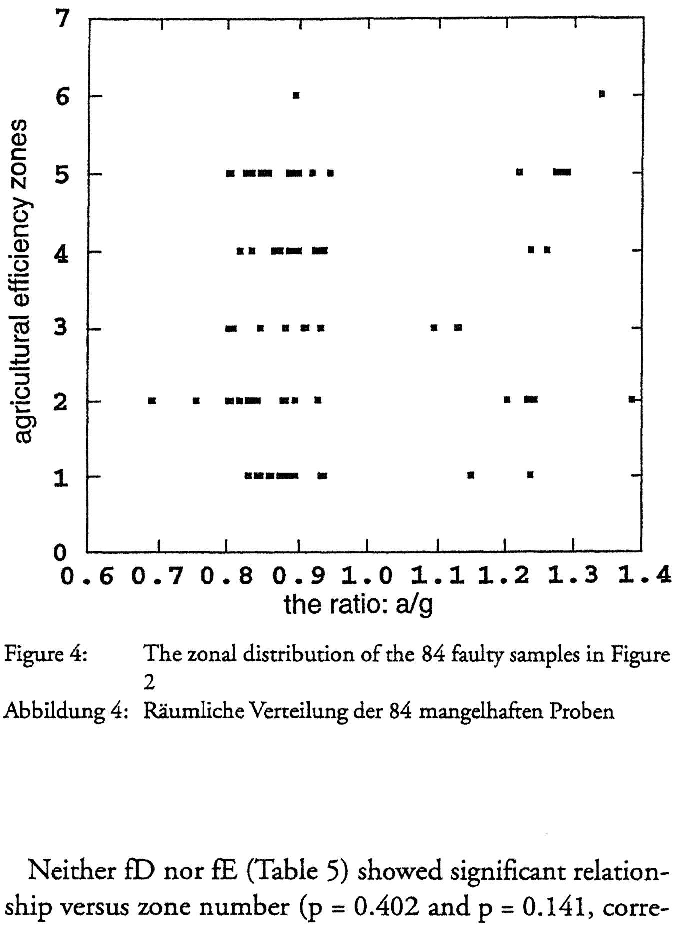

Figure 4: The zonal distribution of the 84 faulty samples in Figure 2

Abbildung 4: Räumliche Verteilung der 84 mangelhaften Proben

Based on all samples, mean b-values for the zones (Table 5), could be regressed versus their respective zone number. The slope of the line was negative, which means that the b-value decreased from zone 1 towards zone 6. The b-value became more negative with increasing zone number which means that the difference between analysed CP and guaranteed CP, versus guaranteed CP, decreased significantly from zone 1 towards zone 6 ($r^2 = 0.265$, $p = 0.034$).

Samples with values upper left or down to the right in Figure 1 are therefore coming more frequently from mills in the highest numbered zones. From Figure 4 however, it can be shown that as the a/g < 1.0 faulty samples are equally distributed among the mills in all zones up to 5, and on all levels, the a/g > 1.0 faulty samples ...

Neither fD nor fE (Table 5) showed significant relationship versus zone number ($p = 0.402$ and $p = 0.141$, correspondingly), but both regressions dropped with increasing number of samples. This means that the largest mills were making the most homogeneous mixes in compliance with the guarantee. None of the relationships, however, followed a linear slope ($p > 0.05$).

The largest mills were from this apparently localised in the southern areas. These are the most efficient agricultural regions according to regulations from the Authorities for agricultural support to farmers (LANDBRUKSDEPARTEMENTET, 1996).

The agricultural conditions are better in south, with greater farms and more animals, better climate and higher efficiency demands and competition. However, the different quality parameters used above did not in a significant way follow the efficiency zones in accordance with tendencies in previous findings (SOEVIK, 1998).

In conclusion it can be stated that analysed CP content in Norwegian feed mixes is higher than guaranteed level. It was also found that the frequency of faults in feed mixes is a linear function of the CP level and that the most frequently produced mixes are least faulty. There has been a significant drop in the fault frequency with time because especially the deficient fraction has diminished. Significant regional quality differences could not be found.

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