Could discrepancy in sodium in a feed mix indicate more fundamental faults?

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Können Diskrepanzen im Natriumgehalt von Futtermischungen grundsätzlichere Mängel anzeigen?

1. Introduction

The sodium level is low in cereals (0.5 gkg^{-1}) but much higher in fishmeal and meals from bone and meat (7.0 gkg^{-1}). When composing diets with statutory levels of sodium and different amounts of various feedingstuffs, sodium compounds therefore often have to be included to comply with the demands.

Extrinsic sodium is often added as finely graded sodium chloride crystals. Sodium chloride is harmful in excess and gives a less tasty feed if the supply is shortened. Small and young animals are most sensitive to fluctuations in the dietary sodium level (HEALY et al., 1994; MCCOY et al., 1994). In either case, an insufficient homogeneity will have an adverse impact on the performance of farm animals.

Consequently, the factories own supervising systems should be expected to be eager in preventing variations in the sodium level in the mixes. In addition, probably no economic benefit could be won by sparing this nutrient.

Differences in milling grade in different types of mixes, often coarse for ruminants and fine for chicks might, however, lead to separations and segregations and inhomogeneity.

A mixing time of 8 min was necessary for reaching 80 % of theoretical homogeneity (LENSER, 1985). Three minutes or longer were sufficient to achieve suitable homogeneity according to ALTI (1994), though even three minutes might often be too long time in real production (BEHNKE, 1996). Usually mixing time will vary from system to system from mixture to mixture and from factory to factory.

Because homogenizing sodium chloride crystals into a batch of milled grain will differ from homogenizing protein or fat, other results as to variation in analysed nutritional content than found for the latter nutrients (SOEVIK, 1998; SOEVIK, 1999), might be expected.

The present survey will treat discrepancy between analysed and calculated content of sodium in fourteen commercial feed mixes for farm animals. The discrepancies will be grouped in deficiencies and excessives and be related to nominal sodium levels. Variation in faults with time will also be monitored because a decrease should indicate an expected general improvement by the industry as a result of great investments in equipment and know-how (CROSTON, 1994). Lastly, could siting of the feed mills in different agricultural efficiency regions influence the frequeny of faults,

Zusammenfassung

Diskrepanzen zwischen analysierten und garantierten Natriumgehalten in 14 Futtermischungen zeigten, dass die Fehlerhäufigkeit zwischen 1,4 % und 16,8% schwankte und sie hatten in den Mischungen ein Ausmaß des 1,15-Fachen des Natriumgehaltes (2 – 12) in g/kg. Gehaltsüberschreitungen waren auf alle Natriumgehalte gleich verteilt. Gehaltsunterschreitungen überwogen bei nominalen Gehalten von mehr als 3 g/kg, was auf verringerte Beimischung natriumreicher Futterkomponenten, wie Fisch- oder Knochenmehl deutete. Abweichungen bei natriumreichen Mischungen stiegen mit der Zeit (8 Jahre) an, während die Fehlerhäufigkeit bei den bedeutendsten Mischungen sank. Die ausgewogensten Mischungen wurden in agrarischen Gunstlagen erzeugt. Die wichtigsten Mischungen waren homogen mit der niedrigsten Fehlerhäufigkeit (2 %).

Schlagworte: Natrium, Futtermischungen, Haustiere, Qualität, Diskrepanzen.

Summary

Discrepancy between analysed and guaranteed sodium content in 14 feed mixes showed that the frequency of faults ranged from 1.4 % to 16.8 %, and had, in any mixture, a magnitude of 1.15 times the value of the sodium level (2–12) in gkg^{-1}. Excessive faults were equally distributed on all sodium levels. Deficient faults were predominant on nominal levels higher than 3 gkg^{-1} which indicated a shortened inclusion of sodium rich feeds like fishmeal or bonemeal. Faults in high levelled sodium mixes increased with time (8 years) while the fault frequency in the most important mixes decreased. The best balanced mixes were produced in the most efficient agricultural regions. The most important mixes were homogeneous with lowest fault frequency (2 %).

Key words: sodium, feed mixes, farmed animals, quality, discrepancy.

and was there a link between faults in sodium and faults in CP? This was the scope of the study.

2. Factories, sampling and analysis

2.1 Feed mills

Eleven factories coded F1 to F11, mixing up to 200,000 tonnes a year have been surveyed. F1 was sited in a northern less efficient agricultural region while F11 was localized in the southern and most efficient region. The distance between F1 and F11 was about 540 km.

2.2 Feeds and mixes

Sodium in a feed mix is the sum of the intrinsic sodium from the ingredients (found in tables) and what is added as pure sodium chloride to reach the statutory level. Feedstuffs in normal use in feed mixes are barley, oats, wheat, wheat brans, sorghum, corn gluten, rape, guarmeal, molasses, soy bean meal, fish meal and bone meal. Further information about the mixes for ruminants, the mixes for pigs and those for poultry is given in Table 1.

2.3 Sampling of feedstuffs and mixes

One sample from a feed mix was drawn on average from every 300 tonnes produced. The sampling, marking and handling procedures were set by the Ministry of Agriculture and were in accordance with international practice for trade in cereals and feedstuffs (LANDBRUKSDEPARTEMENTET, 1964). When the chemical content of a mix by analysis was found to be outside the statutory range, the mix had to be adjusted promptly to achieve compliance with the formula.

Table 1: Three mixtures for ruminants (R1-R3), four for swine (S4-S7) and seven for poultry (P8-P14) after increasing sodium content in gkg^{-1}, statutory sodium range, CP % (SOEVIK, 1998), number of samples and number of faulty samples with excessive and deficient sodium content

Tabelle 1: Drei Mischungen für Wiederkäuer (R1-R3), vier für Schweine (S4-S7) und sieben für Geflügel (P8-P14) nach aufsteigendem Natriumgehalt, gesetzlicher Toleranz, Gehalt an verdaulichem Eiweiß (SOEVIK, 1998), Zahl der Proben insgesamt und der mit Über- bzw. Unterschreitung des Natriumgehaltes

Mixture	Sodium	Range	CP	Samples	Excessives	Deficients
R1	3.0	2.0-4.0	15	1782	21	45
R2	3.0	2.0-4.0	15	176	2	2
R3	6.5	5.0-8.0	38	380	12	52
S4	2.0	1.0-3.0	18.5	266	11	1
S5	2.0	1.0-3.0	14.5	357	10	2
S6	2.0	1.0-3.0	16.5	948	14	4
S7	12.0	10.0-14.0	39	61	1	6
P8	2.0	1.0-3.0	14	254	7	3
P9	2.0	1.0-3.0	15.5	821	14	7
P10	2.0	1.0-3.0	15.5	1004	10	4
P11	2.0	1.0-3.0	16	168	6	0
P12	2.0	1.0-3.0	20	286	8	2
P13	2.0	1.0-3.0	22	142	3	2
P14	4.0	2.0-6.0	22	140	1	9

Values obtained over some weeks were required to have an average as guaranteed.

2.4 Analysis

Necessary chemical analyses of feeds and finished mixes were carried out by recognised methods by the same laboratory. The distribution of analytical errors should therefore be random.

The testmaterial was hammermilled with a screen size of 0,1 mm and homogenized before the chemical analyses were carried out.

The content of dry matter in the sample was found gravimetrically after drying for 3 hours at 105° C (HARDY, 1989). The test substance was dry ashed at 550° C for 3h, then dissolved in concentrated hydrochloric acid and the sodium level was analysed in a diluted solution by atomic absorption spectrofotometry using a sodium lamp. The analytical procedure was authorised by the Ministry of Agriculture and currently in accordance with recommended practice.

2.5 Statistical treatment

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

The number of samples was denoted nS. Faulty samples (nT) were samples with analysed sodium level outside the statutory range. They could be the sum of those deficient (nD) in sodium, and those having sodium in excess (nE). The frequency of faults (fT) was calculated by means of the expression: nT X 100 %/ nS. The years were denoted Y1 to Y8.

3. Results and discussion

3.1 Faults vs. sodium level

The number of samples is given in Table 1.

There were more mixes on the lower sodium levels than on the higher.

The arithmetic mean fault frequency value for these fourteen mixes could be calculated to 5.0 %. The calculation is based on sample values between 61 and 1782. The discussion is concerning the faulty samples and their distribution and variation.

78 % of the faults were deficient in sodium and about 22 % of the faulty samples had sodium in excess. The excessive value is higher than corresponding findings both for CP (SOEVIK, 1998) and for fat (SOEVIK, 1999). It is valid for the three types of mixtures regardless of sodium level, milling grade and ingredients. Compared to a corresponding calculation based on CP values (SOEVIK, 1998), the precision was much lower for the sodium values. This could reflect the difficulties in homogenizing milled feeds and crystallized sodium chloride. The number of faults in sodium, was fewer than in the CP survey. This could influence the results, though also the smallest values in the CP survey were sited on the line.

Though each type of mixture had its characteristics as to ingredients, number of feedstuffs, milling fineness etc., the regression of the frequency of faults, on the statutory sodium levels in gkg^{-1}, (Na) was significantly linear:

$$fT = 1.13 + 1.15 \times Na; \; (r^2 = 0.603, p = 0.001) \qquad (1)$$

The line had a positive slope. This means that the fault frequency was a constant multiple of the sodium concentration. It's magnitude was 1.15 times the sodium level in gram per kilo which means that the frequency of faults was highest in the mixtures with the highest sodium concentrations. This trend was in accordance with previous findings for CP (SOEVIK, 1998) and fat (SOEVIK, 1999).

There was also a linear correlation (p = 0.003) between the frequency of faults and the statutory coefficient of variation of the sodium levels.

The high sodium mixes, R3, S7 and P14, were great contributors to the total frequency of faults. They comprised 8.6 % of the total number of samples and 31.3 % of the faulty samples. While the difference was small between the percentage of deficient- and the percentage of excessive faulty samples among all samples (1.3 : 1), there was a significant higher frequency of deficient faults than excessive faults among the high sodium mixtures (4.8 : 1) (p = 0.037). The corresponding ratio for the mixtures explicit R3, S7 and P14 was 0.8 : 1.

The frequency of deficients was lower than the excessives for sodium values less than 3 gkg^{-1}.

CP is the most central nutrient in composing a diet. Most feedingstuffs are, however, contributors of both CP and sodium. There is a close relationship between CP and sodium level in the most used feedingstuffs in mixes (p = 0.025). The level of sodium in cereals and oilseeds is only one tenth of the level in those of animal origin.

In the present fourteen feed mixes too, the correlation was significant for sodium level versus CP level ($r^2 = 0.77$, $p < 0.001$).

The frequency of faults in sodium also reached a high level of significance when regressed on CP level:

Two conditions may explain this. First, if some of the fishmeal or bone meal in a mixture was replaced by soy bean meal or cereals, this could give a reduced CP level in the finished mixtures. This has been indicated previously (SOEVIK, 1998). Secondly, a reduced level of fish- or bonemeal could also give a reduced intrinsic sodium level mainly in the high protein mixes, if the sodium fortification was kept unaltered. As sodium level and CP level in feedstuffs were positively correlated, faults in sodium could appear if some fishmeal or bonemeal was substituted by cereals containing about 10 % CP. The present results might confirm that such exchanges have taken place.

3.2 Variation in faults with time

The number of annual samples varied between 731 and 924. This appears from Table 2. Only R1 had a significant ($p = 0.009$) decrease in fault frequency with time. Also R2, S4, P9 and P11 had negatively sloped regression lines but their level of significance was higher than 0.05. The overall frequency of faults had a decreasing tendency with time, though a significant linearity could not be shown ($p > 0.05$). The fault frequencies for the three mix types showed no significant differences ($p > 0.05$). The average slope was negative for the ruminant and poultry mixes.

No significant trend could be found when splitting the frequency of faults into an excessive- and a deficient percentage. Both categories, however, showed decreasing tendencies with time. In this context the industry showed improvement. The variations were most obvious the first five years.

Over the sampled period the faults in the high sodium mixes (R3, S7 and P14) increased relatively more than in the

Table 2: The number of samples (nS), the number of excessive faulty samples (nE) and the number of deficient faulty samples (nD), during year Y1 to year Y8. The slope (b) of the linear regression of the frequencies (f) of (nE+nD) on time in year is tabulated for each mix

Tabelle 2: Zahl der Proben insgesamt (nS), fehlerhafter Proben mit Über- (nE) bzw. Unterschreitung (nD) während der Beobachtungsjahre (Y1 bis Y8) samt Steigung (b) der Regressionsgeraden für die Fehlerhäufigkeit im Zeitablauf

	Mixture[1)]													
	R1	R2	R3	S4	S5	S6	S7	P8	P9	P10	P11	P12	P13	P14
Y1-nS	50	13	14	142	84	182	8	42	108	38	23	32	15	36
Y1-nE	3	1	0	10	2	6	1	2	4	0	3	1	2	0
Y1-nD	7	0	0	0	1	1	0	0	1	0	0	0	0	0
2Y-nS	150	9	33	-	91	244	11	52	109	101	21	50	17	17
2Y-nE	3	0	1	-	4	2	0	0	1	1	0	2	0	1
2Y-nD	7	0	9	-	0	0	1	0	1	0	0	1	0	0
3Y-nS	132	8	28	22	53	181	10	43	89	66	17	41	19	22
3Y-nE	0	0	1	0	0	0	0	0	1	0	1	0	0	0
3Y-nD	12	0	3	0	0	0	1	0	1	0	0	0	0	0
4Y-nS	204	14	52	56	65	159	13	43	106	100	23	48	14	27
4Y-nE	2	0	0	0	0	0	0	2	2	0	1	1	0	0
4Y-nD	12	0	10	0	0	2	0	0	1	1	0	0	0	2
5Y-nS	272	24	66	25	39	97	4	29	110	156	16	30	20	15
5Y-nE	2	1	0	0	1	1	0	2	1	3	0	1	0	0
5Y-nD	1	1	9	0	0	1	1	2	1	2	0	0	2	6
6Y-nS	285	27	62	19	21	78	8	19	113	179	19	31	17	11
6Y-nE	10	0	4	1	3	5	0	1	1	3	0	1	0	0
6Y-nD	3	1	12	1	1	1	2	1	0	0	0	1	0	1
7Y-nS	303	25	58	2	4	7	2	15	90	167	15	25	17	7
7Y-nE	0	0	1	0	0	0	0	·0	1	2	0	0	0	0
7Y-nD	1	0	2	0	0	0	0	0	1	0	0	0	0	0
8Y-nS	386	56	67	-	-	-	5	11	96	197	34	29	23	5
8Y-nE	1	0	5	-	-	-	0	0	3	2	1	2	1	0
8Y-nD	2	0	8	-	-	-	1	0	1	0	0	0	0	0
b	-2.21	-0.41	0.41	-0.25	0.76	0.15	0.92	0.09	-0.08	0.18	-1.10	0.20	0.63	0.36

1) The mixtures are the same as in Table 1.

other mixes. The b-values were 0.41, 0.92 and 0.36 respectively. As pointed out above, the deficient faults were more prevailing than the excessive faults in the high sodium mixes.

The tendency was that the faults in the high sodium mixes increased with time while the faults in the other mixes actually decreased. This was also found for faults in CP (SOEVIK, 1998).

The faults in sodium were probably bound to the shortage in CP in the high sodium (and CP) mixes. The industry therefore has an improving potential in these mixes that immediately will influence also the overall fault frequency values. A tendency towards improvement, however, should already have been expected in any randomly selected eight year period, because of the great investments at all levels in the industry during the last decades (CROSTON, 1994).

3.3 Faults versus factory siting

Faults in CP have previously shown an inverse relationship versus distance from F1 ($p < 0.05$) (SOEVIK, 1998).

Above it was pointed out that the high sodium mixes, R3, S7 and P14 had excessive fault frequencies like the other mixes, but larger frequencies of deficient faulty samples than the others.

Table 3 shows that some factories had high fault frequency in all types of mixes. Except for F1 and F7, however, all factories had significantly higher fault frequency in the high sodium mixes than in the others ($p = 0.034$), when using a t-test and categorizing by factory. This can be found from Table 4.

When regressing the frequency of deficiency- and excessive faults versus factory number for all mixes, the regression lines were negatively sloped though the level of significance was not acceptable. There was no significant difference between fE and fD.

If the values for the high sodium mixes (R3, S7, P14), were used, both regression lines had positive slopes; the excessive line being the steepest.

If, however, the values from F11 were omitted, the excessive line turns horizontal and the deficiency line becomes negatively sloped. This means that the difference between excessives and deficiencies was reduced when moving from F1 to F10 and treating F11 as an outlier. The high sodium feed mixes become better balanced when moving towards F10. The mean deficiency value was significantly (p =

Table 3: The frequency of faults fT in the samples nS, taken from factory F1 to F11
Tabelle 3: Fehlerhäufigkeit (fT) in den bei den Mischfutterwerken (F1 bis F11) gezogenen Proben (nS)

	Mixture[1]													
	R1	R2	R3	S4	S5	S6	S7	P8	P9	P10	P11	P12	P13	P14
F1-nS	109	-	1	6	36	78	-	-	78	52	-	13	-	5
F1-fT	1.83	-	0.0	0.0	6.56	2.56	-	-	2.56	0.0	-	7.69	-	0.0
F2-nS	78	5	28	9	30	48	-	32	58	38	-	38	-	4
F2-fT	0.0	0.0	17.86	0.0	0.0	2.08	-	6.25	1.72	2.63	-	0.0	-	0.0
F3-nS	137	6	44	17	26	51	-	4	68	64	-	-	-	2
F3-fT	0.73	0.0	9.09	23.53	3.85	3.92	-	25.0	4.41	1.56	-	-	-	0.0
F4-nS	254	43	79	18	47	108	-	49	109	106	-	23	-	57
F4-fT	16.14	9.3	25.32	16.67	6.38	4.63	-	10.2	2.75	2.83	-	4.35	-	14.0
F5-nS	244	11	59	17	40	83	1	45	97	126	2	31	1	5
F5-fT	1.64	0.0	22.03	0.0	5.0	0.0	0.0	0.0	3.09	1.59	0.0	0.0	0.0	0.0
F6-nS	225	4	67	19	43	83	16	35	105	86	5	49	5	28
F6-fT	1.33	0.0	14.93	0.0	6.98	6.02	6.25	2.86	2.86	0.0	20.0	10.2	40.0	0.0
F7-nS	24	-	2	3	14	30	-	10	27	29	-	-	-	1
F7-fT	4.17	-	0.0	33.3	0.0	3.33	-	0.0	0.0	0.0	-	-	-	0.0
F8-nS	87	6	23	37	31	75	13	18	52	59	21	11	-	16
F8-fT	4.6	0.0	8.7	2.7	3.23	9.33	7.69	5.56	1.92	8.47	14.29	0.0	-	6.25
F9-nS	430	44	34	86	40	229	22	22	103	229	87	56	55	11
F9-fT	2.09	0.0	5.88	2.33	0.0	0.87	13.64	0.0	0.97	0.0	1.15	0.0	0.0	0.0
F10-nS	115	26	28	24	28	92	6	23	67	152	52	49	41	10
F10-fT	0.0	0.0	0.0	0.0	0.0	0.0	16.67	0.0	1.49	0.0	1.92	0.0	0.0	10.0
F11-nS	79	31	15	30	22	71	3	16	57	63	1	16	40	1
F11-fT	1.27	0.0	53.33	3.33	0.0	0.0	33.3	0.0	5.26	3.23	0.0	18.75	7.5	0.0

[1] The mixtures are the same as named in Table 1.

Table 4: The number of samples nS, frequency of faults, fT (that could be excessive fE, or deficient fD), for all mixes, the most concentrated mixes (R3, S7, P14) and the most produced mixes (R1, S6, P10) in each animal feed category, and shown for the mills F1 to F11

Tabelle 4: Probenzahl (nS), Fehlerhäufigkeit (fT) (sowohl Gehaltsüber- (fE) als auch -unterschreitung (fD)) für alle Mischungen, die natriumgehaltvollsten (R3, S7 und P14) und die meistproduzierten (R1, S6, P10) Mischungen in jeder Futterkategorie, dargestellt für die Mischfutterwerke F1 bis F11

mill	all mixes				R3, S7, P14				R1, S6, P10			
	nS	fT	fE	fD	nS	fT	fE	fD	nS	fT	fE	fD
F1	378	2.38	1.59	0.79	6	0.0	0.0	0.0	239	1.67	1.67	0.0
F2	368	2.72	0.82	1.90	32	15.6	3.13	12.5	164	1.22	0.0	1.22
F3	419	4.06	3.10	0.96	46	8.70	0.0	8.70	252	1.59	1.59	0.0
F4	893	10.8	2.35	8.40	136	20.6	1.47	19.1	468	2.78	1.28	1.50
F5	762	3.15	0.66	2.49	65	20.0	0.0	20.0	453	1.32	0.44	0.88
F6	770	4.42	2.86	1.56	111	9.91	1.80	8.11	394	2.03	1.52	0.51
F7	140	2.14	1.43	0.71	3	0.0	0.0	0.0	83	2.42	1.21	1.21
F8	449	4.68	4.45	0.22	52	7.69	5.77	1.92	221	4.52	4.52	0.0
F9	1448	1.11	1.04	0.35	67	7.46	2.99	4.48	888	1.24	1.13	0.11
F10	713	0.56	0.14	0.42	44	4.55	0.0	4.55	359	0.0	0.0	0.0
F11	445	4.94	2.70	2.25	19	47.4	21.1	26.3	213	1.41	0.94	0.47

0.017) larger than the mean value for the excessives. The same pattern was also found when CP was the parameter (SOEVIK, 1998).

The greatest and most important mixture by volume in each category (R1, S6, P10), had excessive and deficiency values that were very close to each other with small absolute values. The regression line for the excessives versus factory number was nearly parallell the horizontal axis.

The deficiency regression was negatively sloped.

The average value for the deficiences was nearly the same as for the excessives. The deficiency values declined towards F11. None of the regressions reached significant levels of acceptance ($p > 0.05$), but the tendencies and trends were unequivocal and in accordance with former findings for faults in CP (SOEVIK, 1998). This could mean that the largest mixes were most homogeneous and least variable both in sodium and in CP. Clearly, the high sodium mixes had a significant ($p = 0.028$) higher frequency of faults (12.9 %) than the most produced mixes (2.54 %) also when categorized by factory.

Though no economic interest are bound to exploiting the sodium limits, the present findings coincide with previous findings on discrepancies in CP when categorizing by nutrient levels, by year of production and by localization of factory. As the most concentrated mixes are most deficient in sodium and CP, this should mean that when diluted on farm, with cereals (ratio 1:5), the final mixes will be deficient in sodium as well as CP, too. For ruminants, access to extra sodium from lick stones will compensate this. For pigs and poultry, suboptimal performance will be the result.

As for faults in CP (SOEVIK, 1998), but contrary to faults in fat (SOEVIK, 1999), the most efficient agricultural regions, where the highest numbered factories are sited, had the most homogeneous mixes with the lowest fault frequencies. This is probably a result of the higher competition on all levels in agriculture in these areas.

If this is a general phenomenon, what then about the increasing trade with feed mixes between countries with different attitudes to competition and quality control?

In conclusion it could be stated that the frequency of faults in any mixture increased linearly with the nominal sodium level between 2 and 12 gkg^{-1}. Deficient faults were predominant in mixes with sodium levels higher than 3 gkg^{-1}. The fault frequency in the most produced and most important mixes decreased during the surveyed period but regional differences could not be shown. Faults in sodium and faults in CP were correlated.

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