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Effect of homogeneity on livestock performance
Bibliographic references

Based on the definition of heterogeneity (i'Tec_H9), it is easy to claim that a product's heterogeneity derives from the presence of non-identical samples. If the samples corresponded to the target animals' daily ration, this would mean that, over the course of a given day, none of the animals would receive an identical ration. This can be quantified statistically very simply using the coefficient of variation (CV) based on the assumption of a Gaussian distribution around the mean determined for one of the feedstuff's chosen ingredients:

- 68% of animals will receive their ration of this ingredient with a variance of ± one CV
- 95% of animals will receive their ration of this ingredient with a variance of ± two CV
- 98% of animals will receive their ration of this ingredient with a variance of ± three CV

Generally speaking, given the presence of additives then, as suggested by Dowler (1988), it may be presumed that "*if a feedstuff has been incorrectly mixed, it will be highly variable in content, with some portions rich in products, and others lacking, which would have a negative impact on the livestock*."

Element	Deficiency threshold (ppm)	Recommended intake (ppm)	Toxicity threshold (ppm)
Copper	7	10	15-30
Cobalt	0.07	0.1	10
Iodine	0.15	0.2	8
Manganese	45	50	1000
Zinc	45	50	250
Selenium	0.1	0.1	0.5

Table 1: Deficiency threshold, recommended intake and toxicity threshold for 6 oligo-elements (according to Meschy, 1993)

Bruggeman and Niesar in 1966 had already indicated that the "*effective dosage is often very low, and occasionally approaches the dose capable of causing imbalances, or even toxicity*." To illustrate this, Meschy (1993) provides meaningful data on oligo-elements (Table 1) indicating that recommended daily intakes are very close to the deficiency thresholds, perhaps to prevent them approaching toxicity thresholds.

Lastly, Jansen (1992) considers that heterogeneity may have an adverse effect on livestock performance in terms of weight gain, mineralisation, etc. It would therefore be useful to look at the findings from certain trials carried out on this topic according to the species under study.

1. Poultry

The company Novus, via Wade Robey (1991), published the findings reported by Duncan in 1989 (Table 2) indicating that animal meals lose a certain amount of homogeneity while travelling between the mixer and the feeding trough, which impacts on the growth of broiler chickens.

	Control	Test 1	Test 2
CV Mixer	-	3.8	8.4
CV Loading	-	4.6	17.8
CV Delivery	-	6.1	19.7
CV Feed trough	-	11.9	27.8
ADG (kg/day)	773 a	716 b	703 c
FCR (kg/kg)	1.74 a	1.82 b	1.86 c

Table 2: Extract of the findings reported by Duncan (cited by Wade Robey, 1991)

Unfortunately, this article specifies neither the chosen homogeneity tracer, nor the age of the poultry, despite clear signs of a homogeneity effect, as indicated by a marked decrease in ADG and an equally significant increase in the feed conversion ratio.

Conversely, McCoy *et al.* (1994) used several tracers to characterise the homogeneity of mixes that were produced for similar tests. Depending on the test, they used the following tracers: chloride ions (NaCl, analysed using the quick Quantab method), sodium ions (Na Cl - dosed by ion-selective electrode), chromium ions, and F-red or blue microtracers. Mixes with various levels of homogeneity were obtained by increasing the number of rotations of the mixer's impeller. The tracers reflected the order of mix homogeneity: 1, 3, 2 (Table 3) which does not coordinate with the number of rotations.

Unfortunately, the results of this first growth trial on 150 chickens from 0 to 24 days did not identify any notable differences in performance according to feedstuff.

Mixes	1	2	3
Number of rotations	20	40	80
CV chlorides (%)	43.0 a	10.8 b	13.1 b
CV chromium (%)	49.7 a	15.3 b	16.7 b
CV red microtracer (%)	50.0 a	14.8 b	17.1 b
CV blue microtracer (%)	47.6 a	12.0 b	14.6 b
ADG (g/d)	31.5	33.4	33.1
Consumption (g/d)	47.5	49.0	48.3
FCR (g/g)	0.663	0.682	0.685

Table 3: Extract of the findings from the first test reported by McCoy *et al.* (1994)

Following this first rather inconclusive test, a second test was carried out on 150 chickens aged from 0 to 28 d. This test was designed to highlight any possible effect of heterogeneity. No significant differences (Table 4) were observed between two intermediate mixes (2 and 3). Only the highly heterogeneous mix (1) gave poor results with a low feed conversion ratio and high mortality rate.

Mixes	1	2	3
Number of rotations	5	20	80
CV chlorides (%)	40.5 a	12.1 b	9.7 b
CV sodium (%)	44.5 a	23.2 b	22.8 b
CV red tracer (%)	53.4 a	16.6 b	11.3 b
CV blue tracer (%)	53.9 a	17.0 b	10.6 b
ADG (g/d)	23.6 a	30.0 b	30.3 b
Consump. (g/d)	43.1	51.5	52.7
FCR (g/g)	0.548 a	0.583 b	0.575 b
Mortality (%)	12	0	0

Table 4: Extract of the findings from the second test reported by McCoy et al. (1994)

The last known trials are those published by Ciftci & Ercan (2003) carried out over 6 weeks on 240 chickens in 3 batches and using sodium chloride as a tracer of homogeneity. They also use the duration of mixing as a stimulator of heterogeneity (Table 5). Chloride CVs with titrimetric analysis range from 38.4% to 7.3%.
Their results show no significant effect on the final average weights of the animals, average daily gains, food intake, feed conversion ratios (Rather high), mortalities, carcass yields, abdominal fat thicknesses. The only effect detected is on the heterogeneity of the final weights which weakens with the increase in the homogeneity of the mixtures.

	Mixing time (mn)		
Mixes	0.2	0.59	3.75
CV Titrimetric Starter	38.4	11.9	7.3
CV Titrimetric Grower	30.4	11.3	9.8
CV Titrimetric Finisher	21.5	14.6	8.9
FCR (g/g)	1.906	1.923	1.869
Mortality (%)	5.00	6.25	3.75
CV weight Male	9.5	8.1	7.4
CV weight Female	10.3	9.6	7.5

Tableau 5 : Extract of the findings from Ciftci & Ercan (2003)

These 4 tests therefore come to different conclusions:

- The Duncan test revealed an effect, but the means by which these results were obtained are poorly understood.
- The tests by McCoy *et al.* did not reveal any effect, or indicated an effect with CVs close to 40 to 50%, while the growth period occurs at the beginning of the chickens' life cycle.
- The Ciftci & Ercan test only perceives an effect on the homogeneity of final weights of animals.

2. Pigs

In 1982, Goransson *et al*. published the results of comparative tests run on various mixes of increasing heterogeneity obtained by various conveyancing modes:

- Mix 1: no conveyancing
- Mix 2: conveyed by a screw conveyor and emptied into a silo fitted with deflectors
- Mix 3: conveyed by a pneumatic conveyor and emptied into an empty silo

Homogeneity was estimated using coefficients of variation calculated, among other things, according to total protein content and ash content. Growth performance was determined for 3 groups of 6 growing pigs at 20 kg to 100 kg (Table 6).

Mixes	1	2	3
CV Proteins (%)	0.7	1.6	2.0
CV Ashes (%)	3.0	3.8	9.8
ADG (g/d) *	577 (a)	562 (ab)	551 (b)
FCR (g/g) *	3.31 (a)	3.44 (ab)	3.55 (b)

Table 6: Extract of the findings from the first test reported by Goransson *et al.* (1982)

These results effectively show a significant deterioration in livestock performance (increase in the feed conversion ratio, reduction in the average daily gain) when coefficients of variation increase.

The trials carried out by Traylor *et al.* (1994) provided further, more detailed, insight that focused on pigs and piglets. Their growth performance was assessed during their consumption of feedstuffs with various levels of homogeneity, produced by varying feed mixing times. The mixes were produced in a double-ribbon horizontal mixer with a holding capacity of 454 kg (impeller speed: 37 rpm) and with a mixing time of 0, 0.5, 2 or 4 minutes. Both tracers (chromium and sodium chloride respectively in each test) demonstrated that, in this mixer, the coefficient never dropped below 5% with a 4-minute mixing time.
The results demonstrate that increased homogeneity has a positive effect on growth and feed conversion ratios in piglets (Table 7), but not in growing-finishing pigs (Table 8).

Mixing time (min)		0	0.5	2	4
CV % (Cr)		106.5	28.4	16.1	12.3
ADG (g)	s	267.6	376.5	381.0	399.2
FI (g)	s	598.7	712.1	703.1	721.2
FCR (g/g)	s	2.24	1.89	1.85	1.81

Table 7: Extract from the findings of the Piglet trials reported by Traylor *et al.* (1994)

S: significant difference between feedstuffs
ns: no significant difference

Mixing time (min)		0	0.5	2	4
CV % (Cl-)		53.8	14.8	12.5	9.6
ADG (g)	ns	775.6	807.4	793.8	784.7
FI (g)	ns	2943.8	2903.0	2884.8	2880.3
FCR (g/g)	ns	3.80	3.60	3.63	3.67

Table 8: Extract from the findings of the Pig trials reported by Traylor *et al.* (1994)

S: significant difference between feedstuffs
ns: no significant difference

The tests run by Traylor *et al*. also revealed that the homogeneity effect is more pronounced in young pigs, where significant differences are observed at every level. Note that feed conversion performance appears to be slightly degraded in pigs (though not significantly) with a CV of 53.8%, but that a CV of 14.8% gives the same results as a feedstuff with a CV of CV of 9.6%.

	Mixer				Trough			
Plans	2	3	4	5	2	3	4	5
ADG lb (ns)	1.88	1.89	1.92	1.84	1.85	1.90	1.93	1.90
ADG lb (s)	6.29	5.97	6.18	6.09	6.40	6.26	6.56	6.51
FCR lb/lb (s)	3.35	3.16	3.22	3.31	3.46	3.30	3.40	3.43
Feedstuff cost $/lb	0.21	0.21	0.22	0.22	0.22	0.21	0.22	0.22
Livestock cost $/pig	42.6	41.4	43.1	43.2	43.9	41.7	44.5	44.7

Table 9: Extract from the findings of tests on sows reported by Johnston *et al.* (1995)

S: significant difference mixer/trough
ns: no significant difference

This would appear to be confirmed by the findings of Johnston et al. (1995), based on tests involving young sows. These tests were designed to compare their diet over the course of 15 weeks based on feedstuffs that had been homogenised either in a mixer, or directly in the feed trough, according to four nutrition plans. Feedstuffs were given ad libitum in the form of meal. Although these tests did not assess homogeneity, the four diet plans systematically highlighted the advantages of homogenising feeds in a mixer, i.e. same ADG, improved FCR, and lower costs (Table 9).
Finally, in 2014, Groesbeck et al. conducted trials on piglets in the first age (0-14 days) and second age (14-28 days). They report that the formulas contain 2 times more components than those of Trailor et al. (1994). There are 5 homogeneities always obtained by growth durations: 0, 30, 60, 120, or 330 s. For each homogeneity, the growths are followed on 6 floors of 6 piglets. The homogeneity is tested by chlorides (400 µm) and proteins.

		Mixing time (s)				
		0	30	60	120	330
0-14j	CV Chlorides bags (%)	26	20	16	11	7
	CV Protein bags (%)	29	14.3	6.1	4.0	2.0
	Gain (g)	190	249	245	256	280
	FI (g)	253	298	275	292	314
	FCR (g/g)	1.33	1.20	1.12	1.14	1.12
14 -28j.	CV% Chlorides bags (%)	56	45	40	33	12
	CV% Protein bags (%)	15.2	14.1	16.1	12.7	3.3
	Gain (g)	473	562	569	595	646
	FI (g)	687	822	793	841	889
	FCR (g/g)	1.45	1.46	1.39	1.41	1.38
	Finishing weight (kg)	15.6	17.6	17.7	18.3	19.3

Tableau 10 : Extract of the findings from trials of *Groesbeck et al.* (2014) with piglets

They conclude from their results (Table 10) that the optimal CV of this study is lower than that of Traylor et al. (1994), because the number of ingredients with low incorporation rates in formulas has increased: 7% in period 1 – 12% in period 2. For them, "*A mixture unsuitable for negative effects on piglet growth performance*".

3. Conclusions

The latest results demonstrate that homogeneity effects are not clear-cut. It can be extremely difficult to identify the simple effect of a single factor when faced with a complex set of associated growth parameters. It would appear, though, that the effects of homogeneity are more pronounced in young animals (chicks or piglets). In their case, a lack of homogeneity might cause deficiencies which could impact on their long-term growth patterns. Other tests would have to be devised to test the effect of varying the prophylactic dosage against varying animal feed patterns, or to identify heterogeneity tolerances validated by the zootechnical impacts.

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