Maternal effects on offspring development in broilers

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Introduction

Development of offspring is influenced by their maternal environment and a mismatch in maternal and offspring environment thus may result in suboptimal development of the offspring. Recently a lot of research has been devoted to the consequences of a match or mismatch in maternal and offspring nutrition level. Results reveal that a mismatch in maternal – offspring environment increases the risk for the offspring to develop metabolic health problems such as diabetes type II, obesity, hypertension, and renal dysfunction (e.g. Barker, D. J. P. (1998); Lumey, L. H., Stein A. D., Kahn H. S. et al. (2007)).

Most of the research related to the consequences of a mismatch in maternal – offspring nutritional environment is related to mammals. Typical of mammals is the extended period of intensive contact between mother and her early developing offspring in utero. This makes it more difficult to clearly distinguish the maternal and the offspring environment. In egg laying species, such as birds, the maternal environmental influence stops at the moment of lay, especially when the effect of brooding is negligible as could be achieved by using an artificial incubator. This makes the bird an ideal species to study the effect of food restriction around conception on the development of the offspring.

The aim of this study was to create a proof of principle in birds that maternal nutritional restriction prior to conception results in adjusted development of the offspring. The broiler was used as experimental animal because its current husbandry system involves a mismatch maternal (restricted) – offspring (ad lib) nutritional environment, and because cardio-vascular problems occur in broilers.

Material and methods

Experimental design. The experiment had a 2x2 factorial design: 2 dietary treatments in the hens and per hen treatment 2 dietary treatments in the offspring. Aim was to achieve a matching and a mismatching treatment in the offspring group as compared to the treatment of their mothers.

Two times 240 60 weeks old pure bred broiler hens of a reproductive dam line (Cobb Europe) were assigned to two feeding strategies: 20% more (approximately ad lib; A) or less

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(R) than their original diet. The feeding strategies were applied for 5 weeks: 4 prior to conception, to assure that the fertilised eggs all had developed during maternal food restriction or abundance, and 1 week after conception to collect the eggs for brooding. In week 5 the hens were inseminated twice, with 3 days in between, with mixed semen of a fast growing pure bred sire line. Eggs were collected and stored at daily basis for 7 days, starting the day after the first insemination, and then brooded in a commercial incubator. At hatch chicks were weighed, tagged with a unique id-number, and transferred to their pens with 13 chicks per pen. The sex of the chicks was only determined at slaughter and in case of mortality chicks were not replaced. In total there were 48 pens, divided over 4 stalls. Each of the four treatments was represented 3 times in each stall, and pen treatments were alternated in a fixed order.

Chicks were fed either ad lib (coded RA if mothers were fed restrictedly or AA if mothers were fed ad lib) or restricted to 70% of ad lib (RR or AR) for a period of 6 weeks. Because sex of the chicks was not available at this stage, an average of estimated male and female intake was used to determine the daily diet for the restricted chicks at pen level. Feed was supplied once a day and sufficient feeding space was made available so that all chicks could eat simultaneously. Water was supplied ad lib for all chicks at all time. Chicks were weighed individually at the start of the experiment (2 days old) and every week until slaughter. Weighing days were day 2, 7, 14, 21,28, 35, and at slaughter. Growth on weekly basis of the chicks was determined by subtracting two subsequent weighings. At slaughter also abdominal fat weight was determined.

Statistical analyses. Growth and body weights were analyzed using a general linear mixed model (Proc Mixed, SAS (2003)) with the effects of maternal feeding level, chick feeding level, and stall as fixed, sex ratio in the pen as covariate, and the effect of individual pen as random in the model. Data collected at slaughter were analyzed with the same model as the growth and weight data, except that day of slaughter was included in the model.

Results and discussion

In Table 1 are the estimated least squares means for weekly growth, and the contrasts of maternal diet in ad lib and restricted chicks. In week 1 the ad lib chicks, the AA males grew faster ($P = 0.026$) than RA males. This effect was not present in the females. In week 4 ($P = 0.068$ in males, $P = 0.042$ in females) the RA chicks grew faster than AA chicks. This effect disappeared in week 5 and 6. But most interesting was growth in week 6. Both in the ad lib ($P = 0.037$) and in the restricted males ($P = 0.022$), offspring of ad lib mothers grew significantly more than those of restricted mothers. This effect was also present, though not significantly in the females.

Results of this study in broilers indicate that offspring of mothers that were restricted in their food intake prior to and around conception show an adjusted growth trajectory as compared to offspring of ad lib fed mothers. This becomes especially evident in the restricted chicks. Both groups of restricted chicks grew at equal speed until week 6. In week 6, even though both groups were on the same diet, the chicks of restricted mothers grew less than the chicks of ad lib mothers. This division seems to point towards a pre-programmed future difference in adult size. It could be hypothesized that the restricted maternal environment has provided cues to the offspring to develop to a lower adult weight. Advantage would be that maintenance costs are reduced so that a larger proportion of the expected resources can be assigned to reproductive effort. In contrast, the ad lib maternal environment may have provided a cue to develop until heavier adult weight. For males (and females?) being heavier will have a competitive advantage and as the environment is expected to be rich, increased maintenance costs are not an issue.

Table 1. Least squares means and estimated contrasts for maternal nutrition for growth in male and female ad lib and restricted chicks.

Week	AA*	RA*	contrast	P-contrast†	AR*	RR*	contrast	P-contrast†
	Males							
1	95.5	88.2	7.3	0.026	81.4	83.3	-1.9	0.449
2	287.9	277.7	10.2	0.18	172.3	170.4	1.9	0.641
3	464.2	454.2	10	0.391	309.7	313	-3.3	0.746
4	586.5	621.8	-35.3	0.068	438.3	433.9	4.4	0.734
5	726.3	704.1	22.2	0.258	642.4	638.1	4.3	0.748
6	865	808	57	0.037	718	670	48	0.022
	Females							
1	82.3	83.6	-1.3	0.639	76.7	77.7	-1	0.681
2	233.1	239.8	-6.7	0.259	164.1	163.4	0.7	0.835
3	365.6	384.7	-19.1	0.042	283.1	282.4	0.7	0.903
4	477.8	500.3	-22.5	0.163	384.3	379.6	4.7	0.644
5	547.2	548.5	-1.3	0.938	520.5	522.8	-2.3	0.824
6	648.6	635.6	13	0.588	586	564	22	0.109

* Least squares means per maternal diet x chick diet group where AA is ad lib maternal and chick diet, RA is restricted maternal and ad lib chick diet, AR is ad lib maternal and restricted chick diet, and RR is restricted maternal and chick diet; † P-values of estimated contrast

In sheep, maternal food restriction prior to conception resulted in approximately 20% reduction in muscle fibers in 75 d old fetuses as compared to fetuses of ad lib fed ewes (Quigley, S. P., Kleemann, D. O., Kakar, et al. (2005)). The lower bodyweight at 6 weeks in the RR chicks as compared to the AR chicks, therefore, is likely to be related to muscle mass. This phenomenon of lower muscle mass in offspring of restricted mothers is also seen in humans (Gale, C. R., Martyn, C. N., Kellingray, et al. (2001)) and rats (Desai, M., Crowther, N. J., Lucas, et al. (1996)). Protein and lipid require approximately the same amount of metabolisable energy per g deposited matter; but protein binds a lot of water, unlike lipid. Per gram of feed intake muscle growth, therefore, results in higher increase in bodyweight compared to fat deposition.

In the ad lib chicks the difference in growth already occurs in week and 4, and the offspring of restricted, and not ad lib, mothers are growing faster. This accelerated growth in offspring of restricted mothers in a rich nutritional environment has also been observed in mammals

(Ozanne, S. E. and Hales C. N. (2004); Ford, S. P., Hess, B. W., Schwope, et al. (2007)). It seems that, if given the opportunity, these animals would grow to their full potential at earlier age than offspring of ad lib mothers. This seems to be supported by increased abdominal fat weight in female ad lib chicks of restricted mothers as compared to ad lib mothers. Compensatory growth is associated with earlier onset of puberty in humans (Karaolis-Danckert, N., Buyken, A. E., Sonntag, et al. (2009)) and monkeys (Coe, C. L. and Shirtcliff, E. A. (2004)). However, offspring of restricted zebra finch mothers that were paired and bred at a fixed time had a lower fecundity than offspring of mothers with a better nutritional status (Gorman, H. E. and Nager, R. G. (2004)). If these results are applicable to chickens, the potential earlier onset of puberty in the rich environment may compensate for the potentially lower number of surviving chicks in a clutch.

These results are interesting for geneticists for 2 main reasons. First, the results in the study may be due to epigenetic changes with respect to methylation status of the DNA. Second, genetic variation in the maternal susceptibility for environmental quality, and in what she 'signals' to her offspring, and in the offspring for susceptibility to 'read' these maternal cues, and to adjust their development accordingly may be used to breed more robust animals.

Conclusion

The results of the study suggest that maternal restricted nutrition has a negative influence on muscle mass in the offspring. Subsequent ad lib feeding in the offspring results in adjustment of the growth trajectory and abdominal fat weight (a measure for obesity), and possibly in reduced fecundity in those chicks. Consequences of a mismatch in maternal – offspring nutrition in a restricted offspring environment, on the other hand, do not seem severe but may depend of the size of mismatch and age of the chicks. These results have not been shown in birds before and suggest a common mechanism in mammals and birds in response to restricted maternal and subsequent ad lib offspring nutritional environment.

References

Barker, D. J. P. (1998) Edinburgh: Churchill Linvingstone. ix, 217 pp. 2nd ed.

Coe, C. L. and Shirtcliff, E. A. (2004) *Ped. Res.* **55**: 914-920.

Desai, M., Crowther, N. J., Lucas, A., and Hales, C. N. (1996) *Br. J. Nutr.* **76**: 591-603.

Ford, S. P., Hess, B. W., Schwope, M. M., Nijland, M. J., Gilbert, J. S., Vonnahme, K. A., Means, W. J., Han, H., and Nathanielsz, P. W. (2007) *J. Anim. Sci.* **85**: 1285-1294.

Gale, C. R., Martyn, C. N., Kellingray, S., Eastell, R., and Cooper, C. (2001) *J. Clin. Endo. & Metab.* **86**: 267-272.

Gorman, H. E. and Nager, R. G. (2004) *Proc. R. Soc. Lond. B.* **271**: 1923-1928.

Karaolis-Danckert, N., Buyken, A. E., Sonntag, A., and Kroke, A. (2009) *Am. J. Clin. Nutr.* **90**: 1559-1565.

Lumey, L. H., Stein A. D., Kahn H. S., van der Pal-de Bruin K. M., Blauw G. J., Zybert, P. A., and Susser, E. S. (2007) *Int. J. Epideiol.* Doi:10.1093/ije/dym126.

Ozanne, S. E. and Hales C. N. (2004) *Nature* **427**: 411-412.

Quigley, S. P., Kleemann, D. O., Kakar, M. A., Owens, J. A., Nattrass, G. S., Maddocks, S., and Walker, S. K. (2005) *Anim. Reprod. Sci.* **87**: 241-251.

SAS/STAT Software. (2003) Release 9.1. SAS Inst. Inc. Cary. NC.