Agrar- und Ernährungswissenschaftliche Fakultät

Christian-Albrechts-Universität zu Kiel
Institut für Tierzucht und Tierhaltung

Effect of nutrient restriction during pregnancy in heifers on maternal and offspring's metabolism

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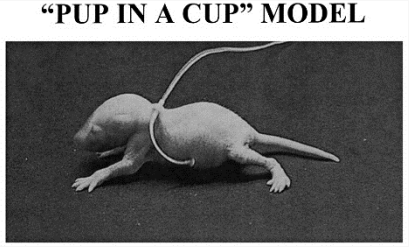
Background

Epidemiological studies in humans

- An unfavorable intrauterine supply influences the metabolic and endocrine pattern of the fetus leading to reduced birth weights and higher risks of developing a metabolic syndrome in adulthood

Experimental studies in rodents

- Early adaptations to a short nutritional stimulus permanently change the physiology and metabolism of the organism and continue to be expressed even in the absence of the stimulus that initiated them.



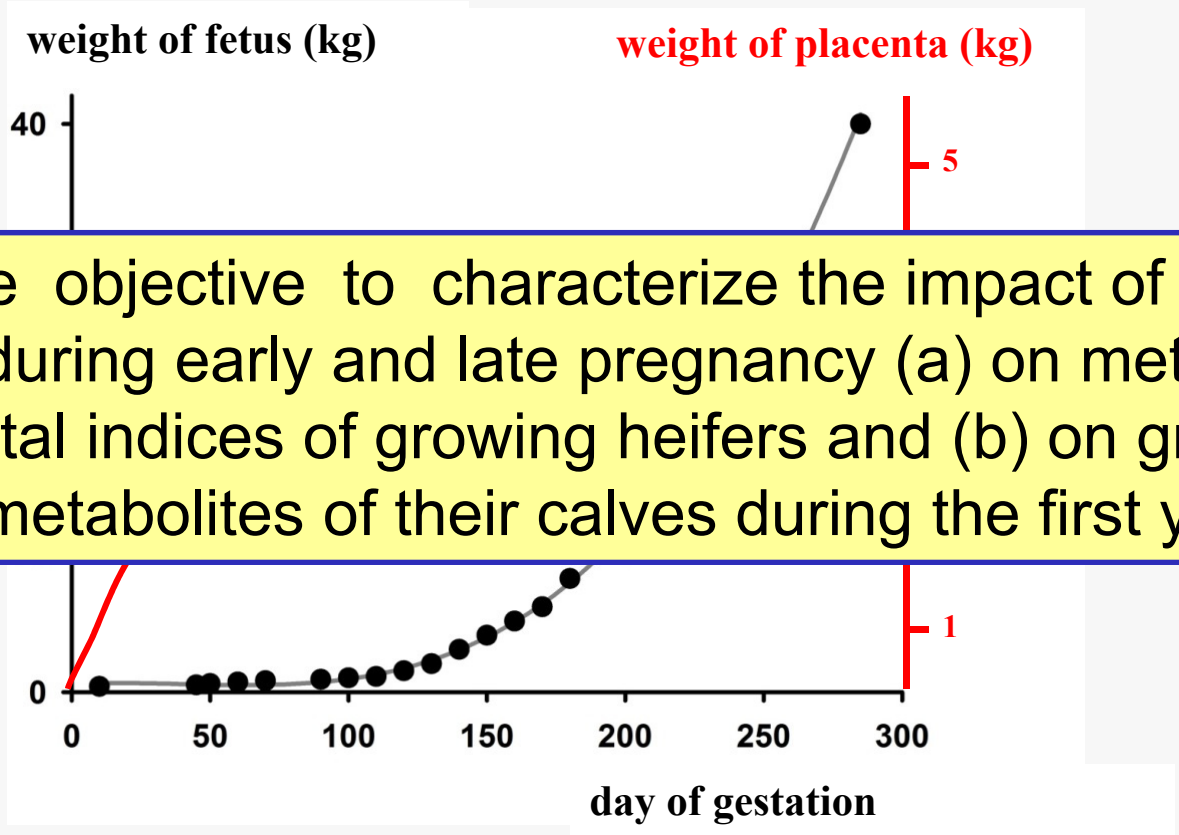
Experimental studies in food animals (mainly pig, sheep, beef cattle)

- Feed restriction during pregnancy seems to affect long-term metabolism, fertility, milk yield and carcass quality of the offspring.

(Hales & Barker 1993, McCance et al. 1994, Plagemann 2003, Srinivasan et al. 2003, Ozanne et al. 2005, Gardner et al. 2005,Ford et al. 2007, Martin et al. 2007, Guilloteau et al. 2009, Rehfeldt et al. 2011)

Background:
- Fetal and placental growth -

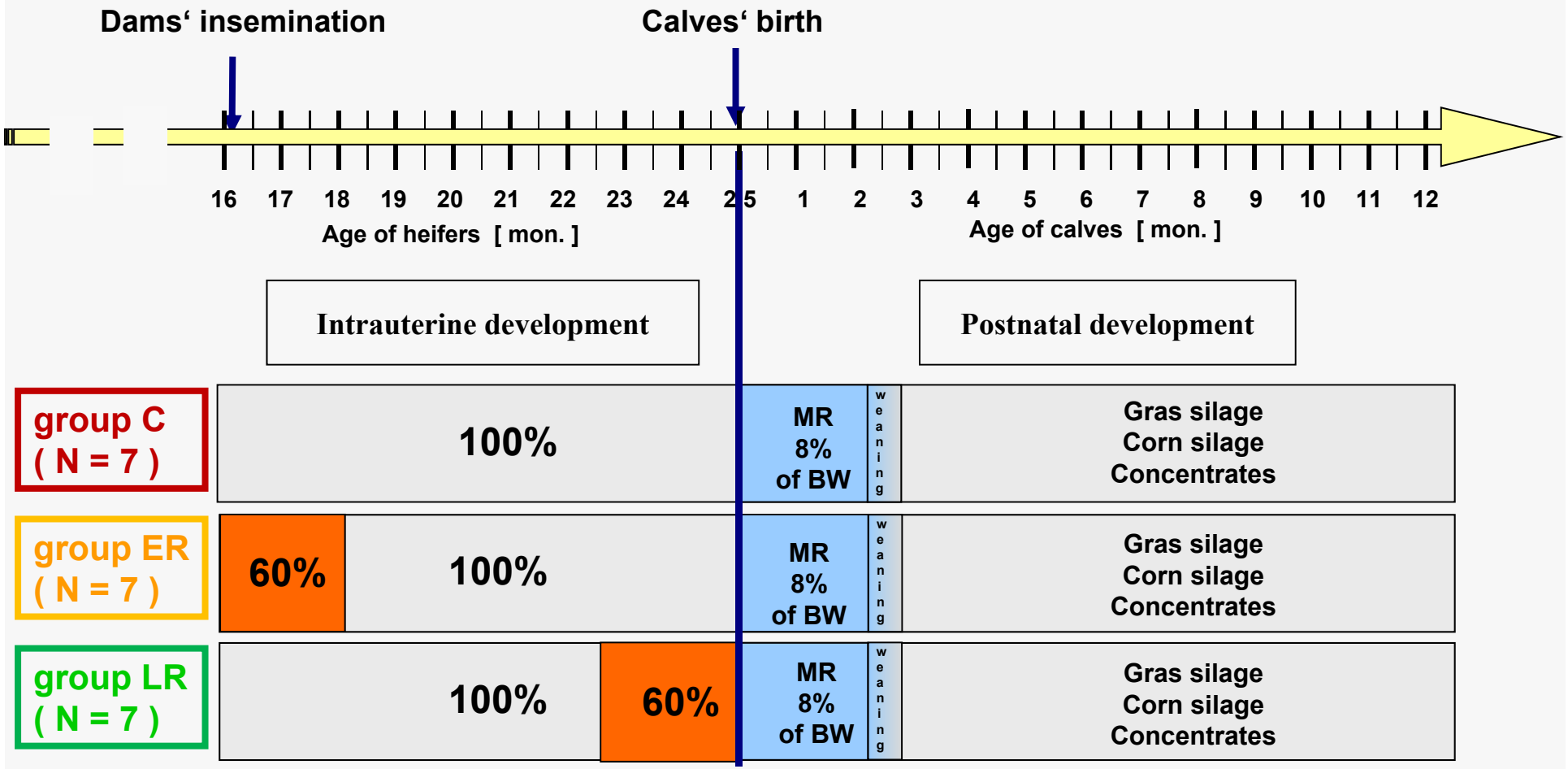
- Placental growth and tissue/organ development of the embryo/fetus are mainly determined during early stages of gestation
- 75 % of fetal growth takes place during the last two months of gestation



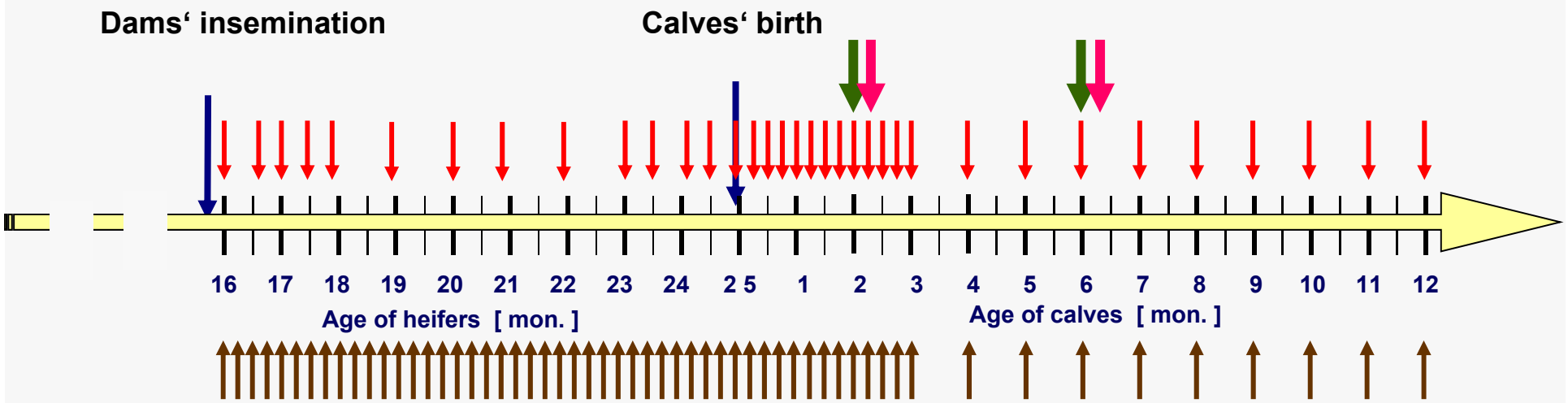
It was the objective to characterize the impact of maternal nutrition during early and late pregnancy (a) on metabolism and placental indices of growing heifers and (b) on growth and key blood metabolites of their calves during the first year of life

(Bauman und Currie, 1980, Robinson et al., 1977, Reynolds et al., 1990, Vonnahme et al., 2007, Sullivan eta al., 2009)

Experimental design
- Animals -



Experimental design
- Parameters -



Body weights

Serum and plasma: metabolic key parameters

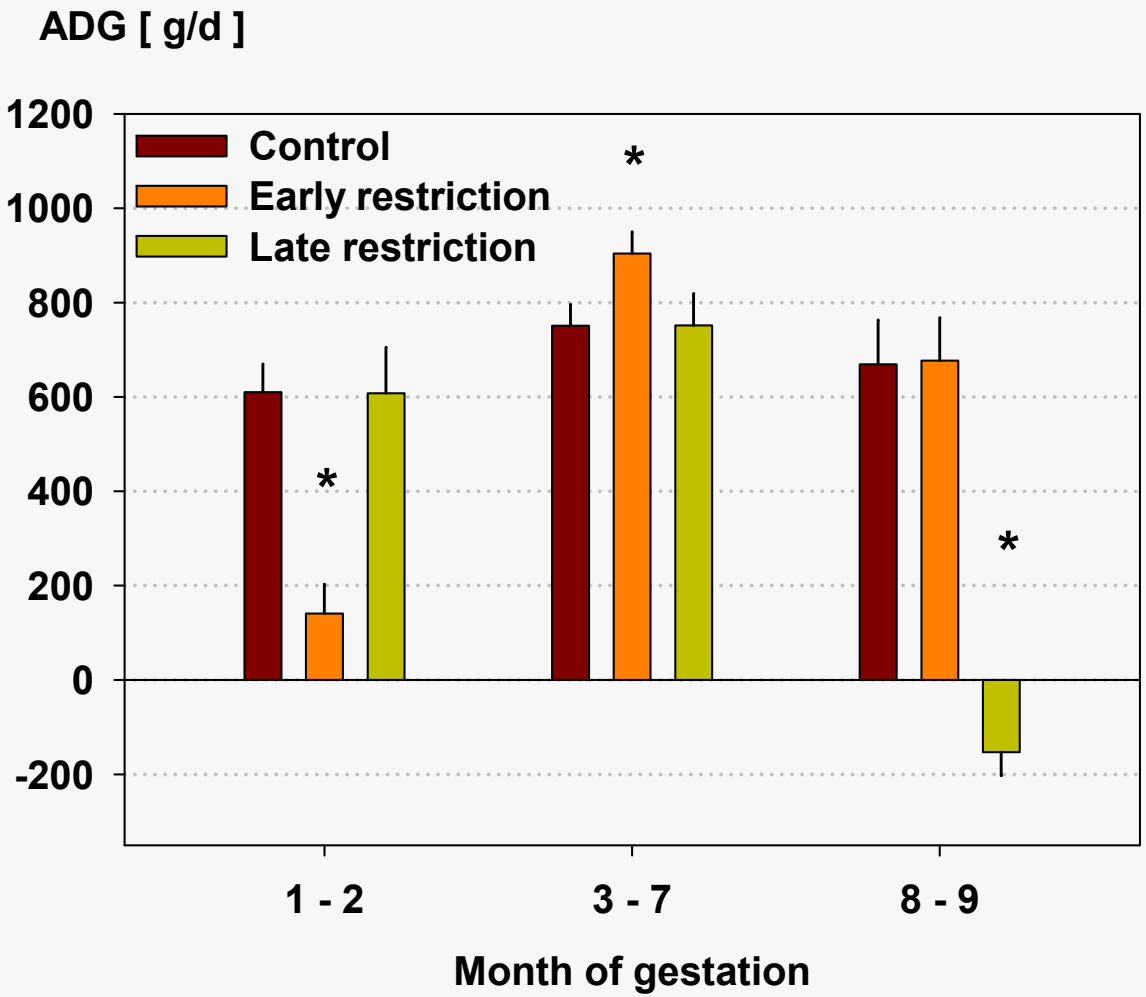
Placenta: weight and size of placentomes

Hyperinsulinemic euglycemic clamp: peripheral insulin response
(6 mU bovine insulin/kg body weight for 3 hours)

Hyperglycemic clamp: pancreatic insulin response
(increase of basal blood glucose by 3 mM for 3 hours)

Statistical analysis: MIXED model with repeated measurements (SAS 9.3)

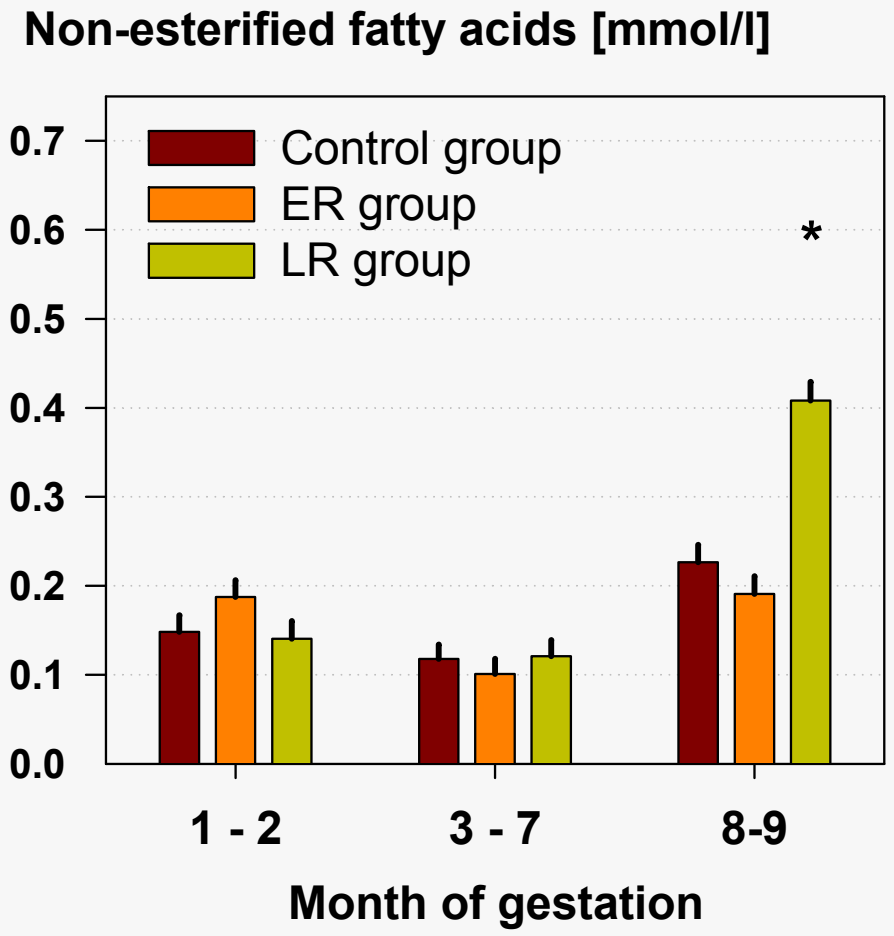
Results
- Average daily weight gain of dams -



A 40% reduction of heifers‘ nutrient intake during early and late gestation results in reduced weight gains.

(Spiegler et al., Ani. Rep. Sci. 2014)

Results
- Metabolic key parameters of dams -



A 40% reduction of heifers‘ nurient intake during early and late gestation only resulted in changes of the NEFA levels towards parturition.

(Spiegler et al., Ani. Rep. Sci. 2014)

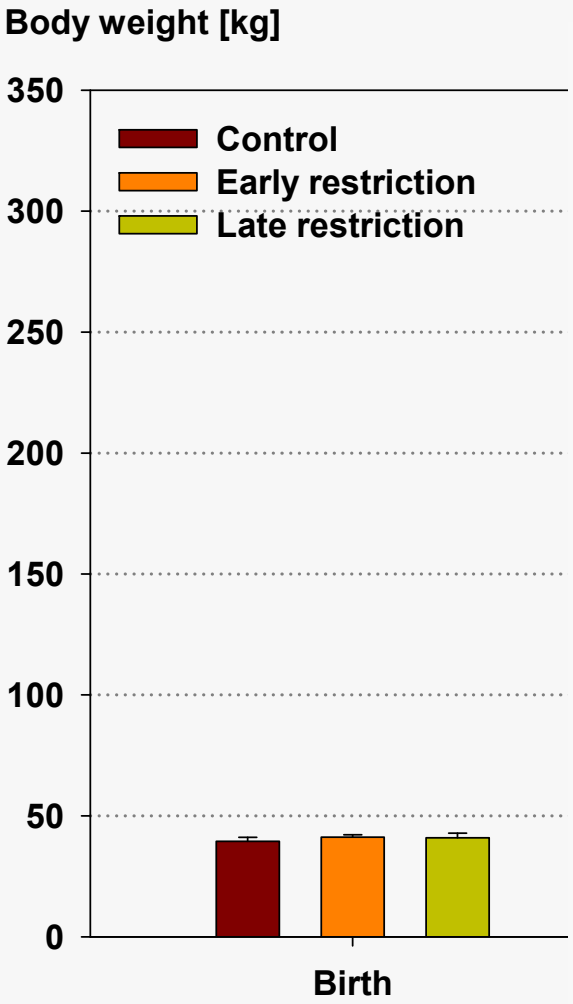
Results
- Placental indices -

	Control	Early restriction	Late restriction	*p*-value	
				Group	Season
Weight of placenta [kg]	5.4 ± 0.4	6.0 ± 0.5	4.8 ± 0.4	0.25	0.81
Area of placen-tomes [cm^{2}]	5,157 ± 426	5,310 ± 567	5,160 ± 530	0.97	0.91

A 40% reduction of heifers‘ nutrient intake during early and late gestation had no effect on assessed placental indices

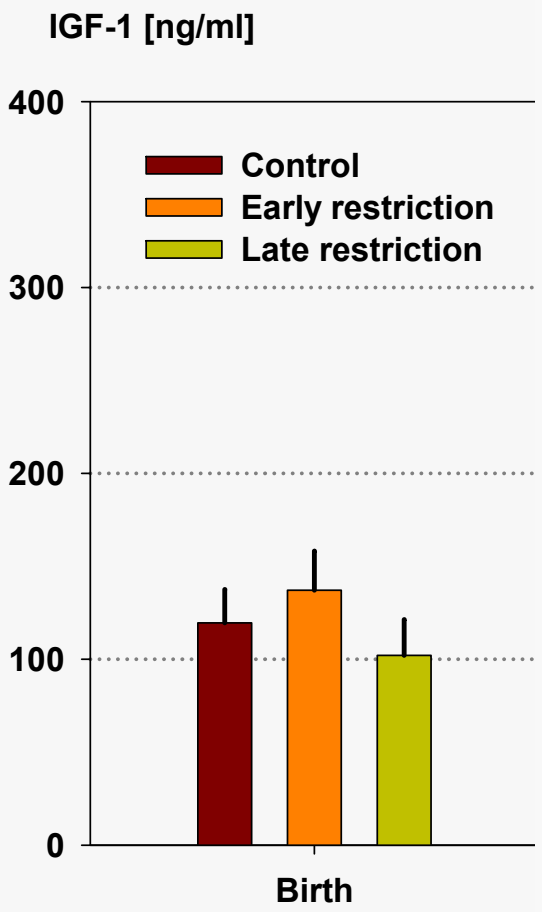
(Spiegler et al., Ani. Rep. Sci. 2014)

Results
- Growth of calves-



A 40% reduction of heifers‘ nutrient intake during early and late gestation had no effect on weight development of calves.

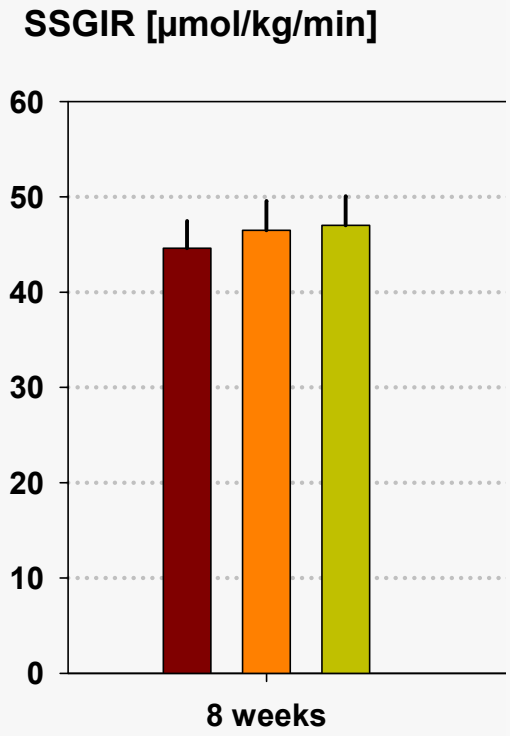
Results
- Metabolic key parameters in blood of calves -



A 40% reduction of heifers‘ nutrient intake during early and late gestation has no effect on metabolic key parameters (e.g. insulin, glucose and IGF-1) of calves.

Results
- Peripheral insulin response -

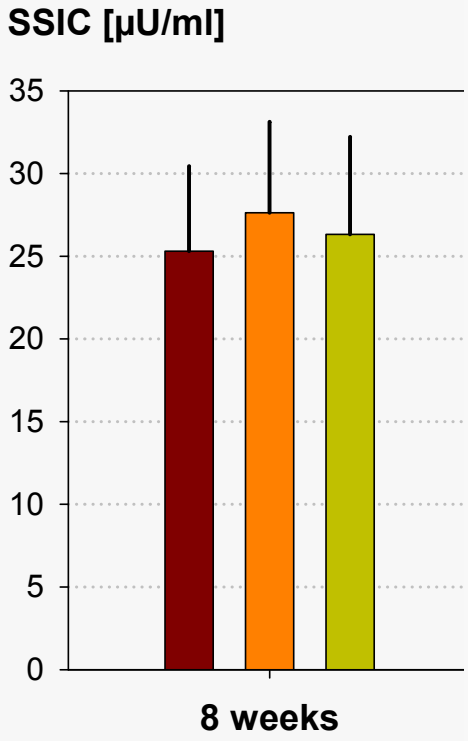
The steady-state glucose infusion rate reflects the peripheral response to an increased blood insulin concentration.



A 40% reduction of heifers‘ nutrient intake during early and late gestation has no effect on the peripheral insulin response during the first 6 months of life.

Results
- Pancreatic insulin response -

The steady-state insulin concentration reflects the pancreatic response to an increased blood glucose concentration.



A 40% reduction of heifers‘ nutrient intake during early and late gestation has no effect on the pancreatic insulin response during the first 6 months of life.

Conclusions

The plane of maternal nutrition in early and late pregnancy

- **affects growth of pregnant heifers**
- **resulted in increased fat mobilization towards the end of pregnancy of heifers**
- **did neither induce significant short-term nor long-term effects on growth, metabolism and glucose homeostasis in heifer calves**

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Thank you for your attention!

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Effect of feeding level on birth weight

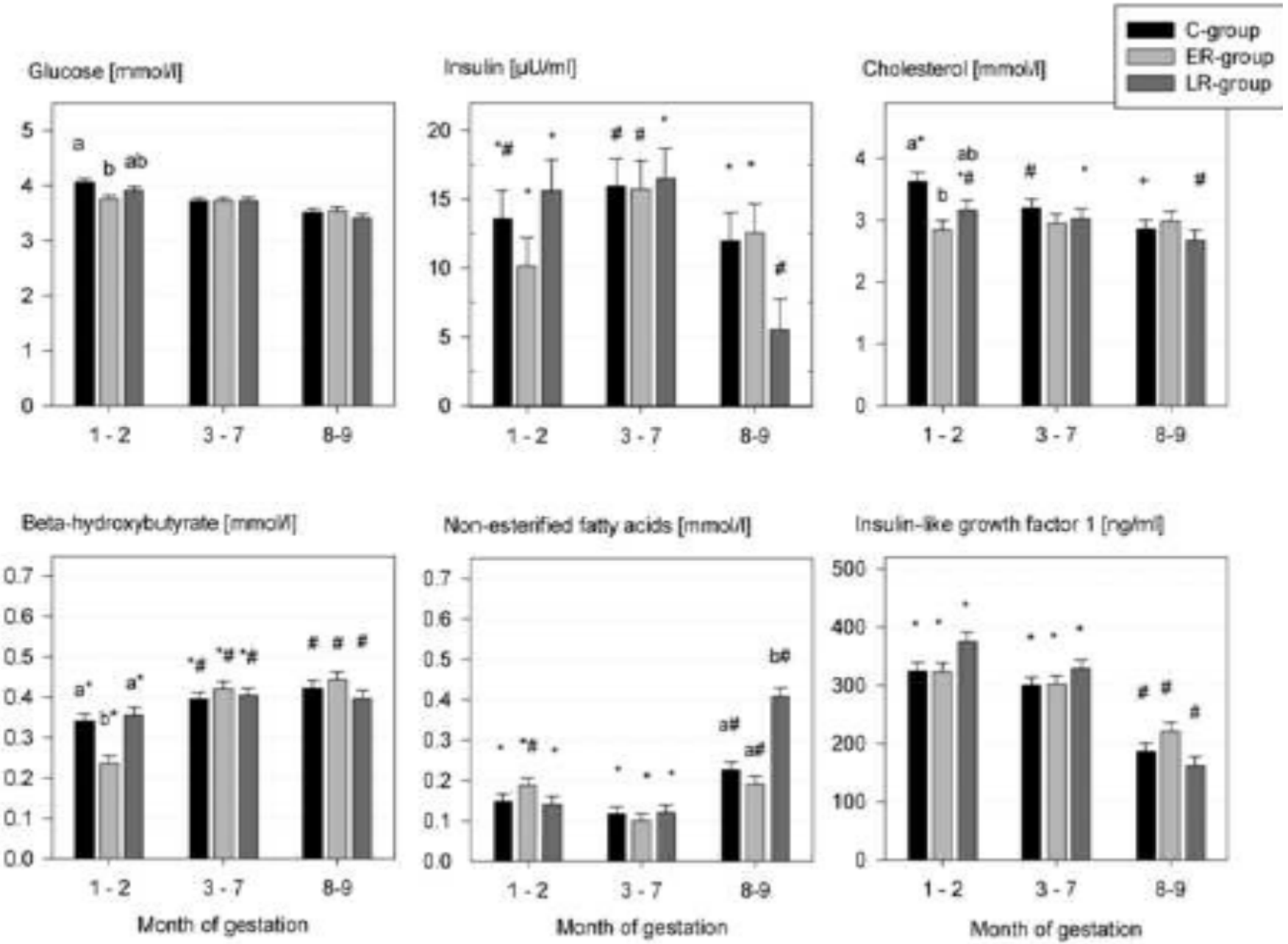
- ✓ Effects of maternal undernutrition on fetal weight in **early pregancy** are inconsistent

Author	N	Restriction period (day)	Restriction level	Fetal growth (slaughter)
Wallace (1948)		28–91		No effect (day 91)
Wallace (1948)		0–90		No effect (day 90)
Everitt (1964)		0–90		Reduced (day 90)
Parr et al. (1982)	228	1-3	5,10,15,20,30 or 40 kg/d	-12,6% on day 35 (10kg / 30kg)
McCrabb et al. (1986)		0–96		No effect (day 96)
McCrabb et al. (1992)		30–96		No effect (day 96)
Arnold et al. (2001)		50–90		No effect (day 90)
Vonnahme et al. (2003)	19	28–78	- 50 %	- 33 % on day 78
Vincent et al. (1985)		0–60		Reduced (birth)
Robinson et al. (1989)		0–40		Reduced (day 90)
Heasman et al. (1998)		28–77		No effect (day 145)
Steyn et al. (2001)		0–70		No effect (day 130)

Effect of feeding level on birth weight

- ✓ Maternal undernutrition in sheep reduces fetal growth in **late pregnancy**

Author	Restriction period (day)	restriction level	Fetal growth (day 130-145)
Wallace (1948)	91–144		Reduced
	28–144		Reduced
Robinson (1977)	0–145		Reduced
Robinson et al. (1979)	0–145		Reduced
Holst et al. (1986)	1–145		Reduced
Mellor (1983) and (1987)	90–145		Reduced
Faichney et al. (1987)	90–145		Reduced
McCrabb et al. (1986)	0–142	- 20%	No effect
Kelly (1992)	90–145		Reduced
Arnold et al. (2001)	50–130		Reduced


C-group
ER-group
LR-group
Glucose [mmol/l]
Insulin [µU/ml]
Cholesterol [mmol/l]
Beta-hydroxybutyrate [mmol/l]
Non-esterified fatty acids [mmol/l]
Insulin-like growth factor 1 [ng/ml]
1 - 2
3 - 7
8-9
Month of gestation

Feeding ration	Composition [% of DM]	Mean energy; [MJ ME/kg DM]	Mean crude protein [% of DM]
TMR 1 (control ration)			
Grass silage	71		
Maize silage	17	9.8	14.1
Straw	12		
TMR 2 (restricted ration)			
Grass silage	43		
Maize silage	10	7.7	10.7
Straw	47		
Concentrate			
Barley	14.9		
Maize	24.8		
Wheat	21.8		
Soybean meal extract	20.1	12.7	19.2
Sugar beet pulp	15.2		
Minerals[1]	2.1		
Feed lime	1.1		

[1] 42.5 % calcium carbonate, 21.0 % sodium chloride, 13.5 % magnesium-phosphate, 9.5 % mono-calcium-phosphate, 4.0 % apple pomace, 3.2 % magnesium oxide, 1.8 % rape oil, trace elements, vitamins A and E

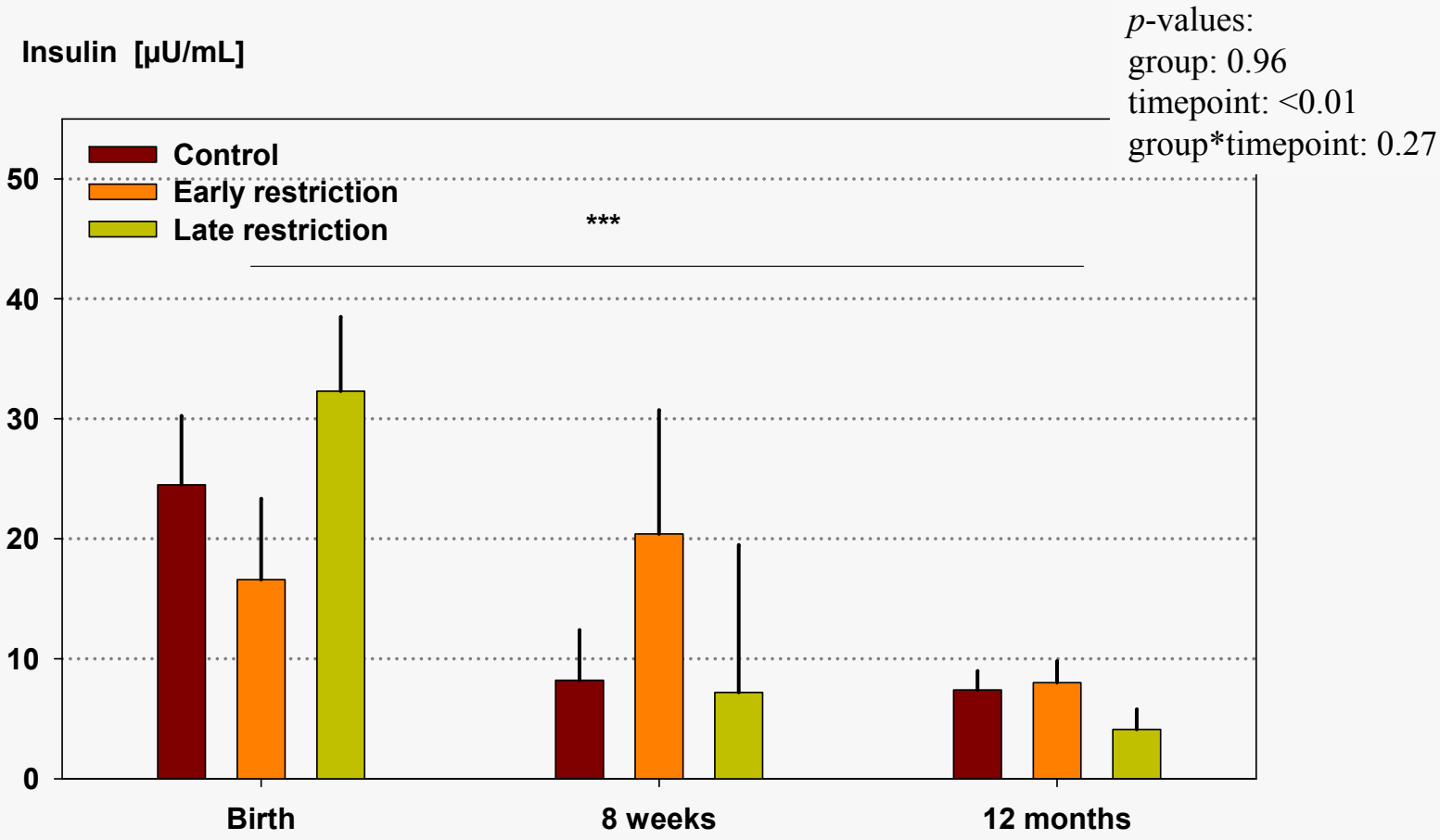
Table 3: Least squares means of daily weight gain, energy intake and crude protein intake during the experimental period [1]

	Treatment group			p-value	
	Control	Early restriction	Late restriction	group	weight at insemination
Energy intake					
Period 1 (MJ ME/d)	80.2 ± 2.0	48.5 ± 2.1*	83.0 ± 2.2	<0.0001	0.005
Period 2 (MJ ME/d)	86.1 ± 1.5	85.9 ± 1.5	86.6 ± 1.5	0.93	0.04
Period 3 (MJ ME/d)	126.2 ± 2.9	123.5 ± 3.0	69.6 ± 3.1*	<0.0001	0.76
Crude protein intake					
Period 1 (g/d)	1,142 ± 35	682 ± 36*	1,183 ± 37	<0.0001	0.22
Period 2 (g/d)	1,230 ± 23	1,233 ± 23	1,224 ± 24	0.94	0.44
Period 3 (g/d)	1,489 ± 38	1,438 ± 39	809 ± 40*	<0.0001	0.47
Average daily gain (ADG)					
Period 1 (g/d)	610 ± 60	141 ± 62*	608 ± 97		
Period 2 (g/d)	751 ± 45	904 ± 46*	752 ± 67	<0.0001	0.84
Period 3 (g/d)	669 ± 94	677 ± 91	-153 ± 50*		
Total ADG during gestation (g/d)	697 ± 30	709 ± 31	582 ± 32*	0.01	0.84

[1] Period 1: first two month of pregnancy; Period 2: third to end of seventh month of pregnancy; period 3: last two months of pregnancy

* group differs to other groups during respective period

Results:
- Blood parameters -



p-values:
group: 0.96
timepoint: <0.01
group*timepoint: 0.27

A 40% reduction of heifers‘ energy intake during early and late gestation has no effect on metabolic key parameters in blood of calves.

Results
- Metabolic key parameters in blood of calves -

- ✓ no differences in cholesterol, Non-esterified fatty acids, beta-hydroxybutyrate, glucose, insulin and IGF-1 concentration in the blood between groups