Influence of mitochondrial function on growth and meat quality in turkey

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Background
Because of the low content of fat turkey meat became very popular. The increasing demand forced breeders to raise up birds faster, with higher weight and especially higher relative content of breast muscle [1]. Over the years this led to inferior meat quality and lower resistance to stress as known from pigs, too [2]. The meat is getting pale, soft and exudative (so called PSE condition). The mostly used BUT BIG 6 turkeys are thought to be more sensible to stress which seems to be of minor importance for the only mildly selected Kelly strain. Recent reports showed an major impact of mitochondrial function on growth and meat quality in pigs [3]. For turkeys in this field virtually nothing is known.

Objective
Comparative analysis between functional, physical, biochemical and histological parameters with focus on mitochondrial function and meat quality. Comparative analysis between a highly selected strain (BUT BIG6) and a moderately selected one (Kelly BBB).

Methods
Animals. Male turkeys of two different strains (BUT BIG 6 and Kelly BBB; 22 each) were purchased from a commercial hatchery at day one of age and grown up at the university's farm. Turkeys were fed at libitum.
Specimen. At week 10 and 20 of age about 200 mg of M. pectoralis major were obtained via needle biopsy from each turkey. The probe was divided to perform the experiments mentioned below. After slaughtering (week 22) EDTA whole blood samples were achieved via neck dissection for measurement of plasma creatine kinase (CK) activity.
Histology. Beside the HE standard staining technique, ATPase reaction according to Horak [4] was applied. At least 200 fibers were morphological analyzed using the semi automated system Lucia M (Nikon).
Enzymology. CK activity was determined photometrically using a Hitachi 911 automatic analyzer.
Mitochondrial function. Maximum respiration rates (state 3) were determined in saponin skinned muscle fibers by high resolution respirometry using several physiological substrates [5]. Respiratory control indices (RCI) were calculated as quotient between state 3 respiration and atractyloside inhibited respiration (state 4). Intactness of mitochondrial outer and inner membrane was proofed with previously described methods [5].
Quality check of meat. Meat quality was tested by measurement of pH 20 min post mortem in the breast muscle using the pH-Star instrument. Lightness (L*-value) was detected by use of the Minolta equipment. Subjective parameters such as flavor, juiciness or tenderness were tested by 6 volunteers, grill yield under standardized conditions.

Results
BUT BIG 6 turkey developed higher carcass weights in relation to Kelly BBB whereas there could be found neither differences in percentage of breast muscle nor in meat quality parameters (Tab. 1). But carcass weight and breast weight show strong correlations with plasma creatine kinase activity ($r=0.81$ resp. 0.88; $p<0.0001$) independent of the strain. Meat quality was classified by means of pH value 20 minutes post mortem. pH values below 5.70 were considered to be a indicator for poor quality. About 60% of the animals fulfilled this criterion. As shown in Tab. 2 this value is confirmed by the subjective parameters tenderness and flavor as well as by the grill yield. Further high breast meat percentage, fiber hypertrophy and high CK activity as well as high mitochondrial respiration rates go ahead with poor meat quality independent of the strain, too. During the experiment 3 animals of the BUT BIG 6 strain died after the 10th week whereas there were no loss of Kelly turkeys.
To clarify the impact of mitochondrial function on meat quality on growth the skinned fiber technique had to be adapted for respirometric investigation of turkey breast muscle. Optimum conditions were found to be a permeabilization procedure of 1 hour with 0.1 µg Saponin / ml buffer.
Whereas only minor differences in state 3 respiration between the two strains could be found, a high individual variance up to an factor of 3.5 was observed. During the phase of fastest growing both strains showed significant higher respiration rates than the adult animals. This can be explained by an age dependent decrease in number of mitochondria. The observation that RCIs for most substrates also decrease but RCI for Succinate does not change, may be due to changes in complex I of the respiratory chain. Interesting is the low utilization of Pyruvate (which is usually the best substrate in mammalian skeletal muscle) in comparison to Octanoylcarnitin, Succinate and Glutamate (Tab. 3). In adult turkeys which developed later poor meat quality (pH<5.7) this finding is significantly more pronounced (ratio pyruvate/glutamate max. respiration for pH20<5.7: 0.61 but for pH20>5.7: 0.80). One possible reason could be a decrease in activity of pyruvate dehydrogenase complex which would have implications especially for glycolysis, since a reduced oxidative capacity of pyruvate utilization could lead to increased formation of lactate. This could be a reason for the rapid post mortal pH decline in turkey muscle, especially for those turkeys developing poor meat conditions.
Taking into account that nearly 100% of turkey's breast muscle consists of white type fibers the observed respiration rates are high compared to mammalians. The increased diameter of the fibers in adult turkeys could cause limitations in oxygen diffusion to the mitochondria.
Using discrimination analysis it is possible to predict meat quality in turkeys using parameters of mitochondrial function (respiration rates, RCIs and indices of intactness of mitochondrial outer membrane) at a probability level of about 95%. Hence mitochondria seem to play a role in the process of conversion from muscle to meat.

Conclusion

- BUT BIG 6 turkeys develop higher carcass weight in comparison to the Kelly BBB strain but do not have any benefit in the percentage of breast muscle.
- There seem to be no meat quality influencing factors that can be contributed to the strain. Depending on the individual animal heavy turkeys show beside distinct biochemical changes hypertrophy of muscle fibers and tend to develop poor meat quality.
- Plasma creatine kinase activity shows a strong positive correlation with muscle mass in turkey.
- Mitochondrial respiration rates are higher in growing animals compared to adult ones. Differences between the observed strains are of minor importance.
- Interesting differences in respect to substrate specificity of mitochondria between mammalians and turkeys exist. Pyruvate respiration is limited by an unknown mechanism which could be an explanation for the rapid post mortal pH decline in turkey.

References

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Tables

Tab.1: Meat parameters of different turkeys depending on the strain. Juiciness and tenderness are scaled from mark 1 to 6 where 1 stands for worst and 6 for best quality. * = significant difference between the different strains. All data as mean ± S.D.

strain	Carcass weight * [Kg]	Breast muscle [%]	Area of fibers (μm^2)	CK-activity * [$\mu mol \cdot s^{-1} \cdot l^{-1}$]	L*-value	Flavor	Tenderness	Grill yield [%]
BUT BIG 6	16.95 ± 2.56	33.76 ± 3.95	7042 ± 2398	971 ± 663	48.03 ± 2.38	2.83 ± 0.51	2.99 ± 0.62	73.27 ± 2.74
Kelly BBB	13.26 ± 2.14	33.67 ± 2.74	5861 ± 1567	610 ± 347	48.04 ± 2.44	2.91 ± 0.37	2.95 ± 0.72	73.59 ± 2.71

Tab.2: Meat parameters of different turkeys depending on intramuscular pH. State 3 respiration rate (Biopsy II) with Malate/Glutamate as substrates is given in $nmol \cdot min^{-1} \cdot mg^{-1}$ s.w.. Juiciness and tenderness are scaled from mark 1 to 6 where 1 stands for worst and 6 for best quality. * = significant difference between the different strains. All data as mean ± S.D.

Meat quality	Carcass weight [Kg]*	Breast muscle [%]*	Area of fibers [μm^2]*	CK-activity * [$\mu mol \cdot s^{-1} \cdot l^{-1}$]	State3 resp. Mal./Glut. *	Flavor *	Tender-ness *	Grill yield [%]*
Poor (pH<5.7)	16.03 ± 2.73	34.90 ± 2.96	7081 ± 2147	1011 ± 521	1.20 ± 0.20	2.76 ± 0.41	2.71 ± 0.51	72.38 ± 2.42
Good (pH >5.7)	13.30 ± 2.59	31.85 ± 3.03	5651 ± 1675	413 ± 346	0.79 ± 0.22	3.04 ± 0.44	3.36 ± 0.70	75.04 ± 2.31

Tab.3: Maximum respiration rates (state 3) in $nmol \cdot min^{-1} \cdot mg^{-1}$ s.w. and Respiratory Control Indices (RCI) measured in skinned muscle fibers of turkey breast muscle. Additionally body weight and mean fiber area are demonstrated. * = significant difference between the different strains; # = significant difference between the two biopsies. All data as mean ± S.D.

Parameter/Substrate		BUT BIG 6		Kelly BBB	
		Biopsy I	Biopsy II	Biopsy I	Biopsy II
Body weight [kg]		8.94 ± 0.70 */#	20.23 ± 2.75 */#	7.21 ± 0.89 */#	16.06 ± 2.33 */#
Area of fibers [μm^2]		3616 ± 952 */#	7042 ± 2398 #	3025 ± 536 */#	5862 ± 1567*/#
State 3 respiration	Malate/Glutamate	1.55 ± 0.26 */#	0.99 ± 0.30 #	1.62 ± 0.32 #	1.08 ± 0.28 #
	Malate/Pyruvate	1.06 ± 0.16 #	0.63 ± 0.17 */#	1.17 ± 0.24 #	0.75 ± 0.15 */#
	Malate/Octanoylcarnitin	0.33 ± 0.07 #	0.18 ± 0.05 */#	0.35 ± 0.08 #	0.21 ± 0.04 */#
	Succinate/Rotenone	1.32 ± 0.18 #	0.89 ± 0.21 #	1.43 ± 0.27 #	1.02 ± 0.19 #
RCI	Malate/Glutamate	10.76 ± 3.59 #	8.44 ± 3.79 #	11.25 ± 3.73 #	8.23 ± 2.61 #
	Malate/Pyruvate	8.10 ± 1.93 #	5.98 ± 3.01 #	8.71 ± 2.76	6.68 ± 2.60
	Malate/Octanoylcarnitin	2.74 ± 0.73 #	2.05 ± 0.52 #	2.74 ± 0.73 #	2.11 ± 0.42 #
	Succinate/Rotenone	4.29 ± 0.98	4.39 ± 0.91	4.35 ± 0.99	4.66 ± 1.03