Prediction of pork quality attributes using metabolic rate and muscle fiber characteristics

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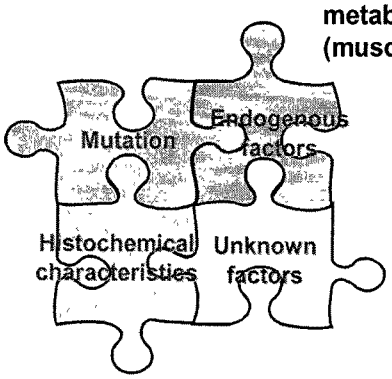
Meat Quality

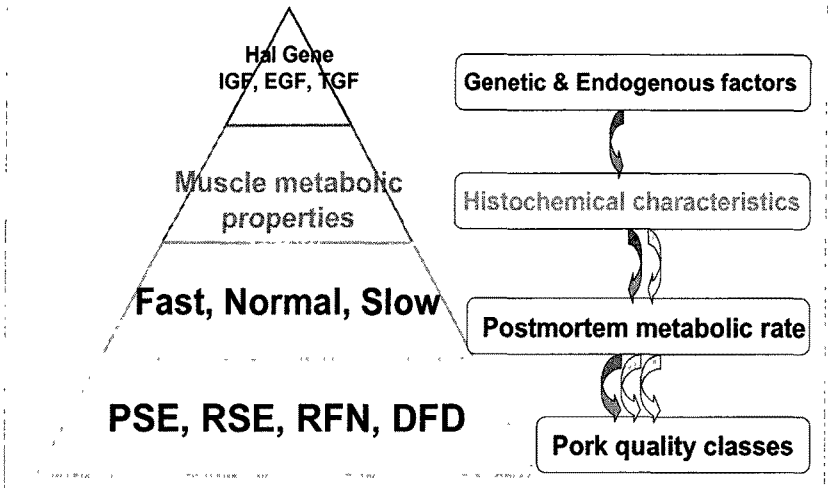
① Extrinsic factors : environmental factors (stress etc.)
postmortem glycolytic rate

② Intrinsic factors : genetic factors (ryr1, RN gene etc.)
metabolic property of muscle
(muscle fiber characteristics)



In pigs

Abnormal pork (PSE, RSE, DFD)
Various glycolytic patterns



Objectives

To investigate the formation of the undesirable pork, particularly concentrated on the muscle intrinsic factors that influenced muscle metabolism **in the period around slaughter and thereby meat quality**

- **Animals** : 231 crossbred Duroc X (Landrace X Yorkshire) pigs
  Halothane-gene-free pigs
- **Samples** : *Longissimus* muscle at 45 min and 24 h postmortem

- **Pork quality classes** (Joo et al., 1999)

- PSE:	drip loss > 6.0%,	$L^* > 50$	(N = 39, 16.9%)
- RSE:	drip loss > 6.0%,	$L^* \leq 50$	(N = 44, 19.0%)
- RFN:	drip loss ≤ 6.0%,	$L^* \leq 50$	(N = 143, 61.9%)
- DFD:	(drip loss < 2.0%),	$L^* < 43$	(N = 5, 2.2%)

Materials and Methods

- **Postmortem metabolic rate group** (Honikel and Fischer, 1977)

- Fast:	$pH_{45min} < 5.80$,	R-value (R_{248}) > 1.05	(N = 48, 20.8%)
- Normal:	$pH_{45min} \geq 5.80$,	R-value (R_{248}) ≤ 1.05	(N = 178, 77.0%)
- Slow:	$pH_{45min} > 5.80$,	R-value (R_{248}) > 1.05	(N = 5, 2.2%)

- Fast group → RFN (27.0%), RSE (16.7%) and PSE (56.3%)
- Normal group → RFN (73.1%), RSE (20.2%), and PSE (6.7%)
- Slow group → classified into only DFD pork.

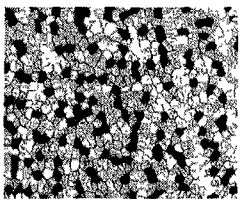
Materials and Methods

- Histochemical analyses

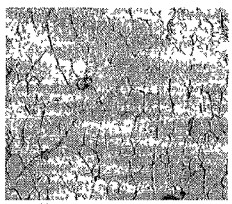
1. **Muscle fiber size:** cross-sectional area, diameter, perimeter
2. **Muscle fiber number:** the density of muscle fiber per mm^2
   total number of muscle fiber
3. **Fiber type composition:** Fiber number percentage
   (Lind and Kernell, 1991) Fiber area percentage

	Type I	Type IIA	Type IIB
Color	Red	Intermediate	White
Metabolism	Oxidative	Oxidative & Glycolytic	Glycolytic
Size	Smaller	Smaller or Intermediate	Larger
Contraction Relaxation	Slow	Intermediate	Fast

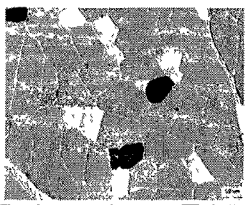
Fiber type composition



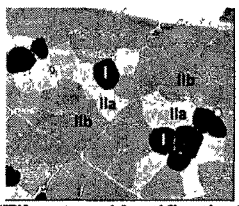
[*Soleus* muscle in chick]



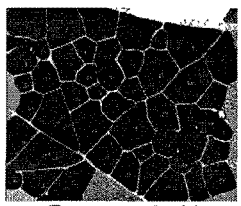
[*Pectoralis major* muscle in chick]



(Preincubation at pH 4.7)



(Fiber type identification)

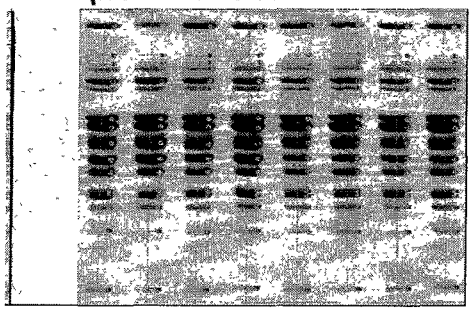


(Image analysis)

[Serial sections of *longissimus thoracis* muscle, stained for mATPase activity in pig]

Materials and Methods

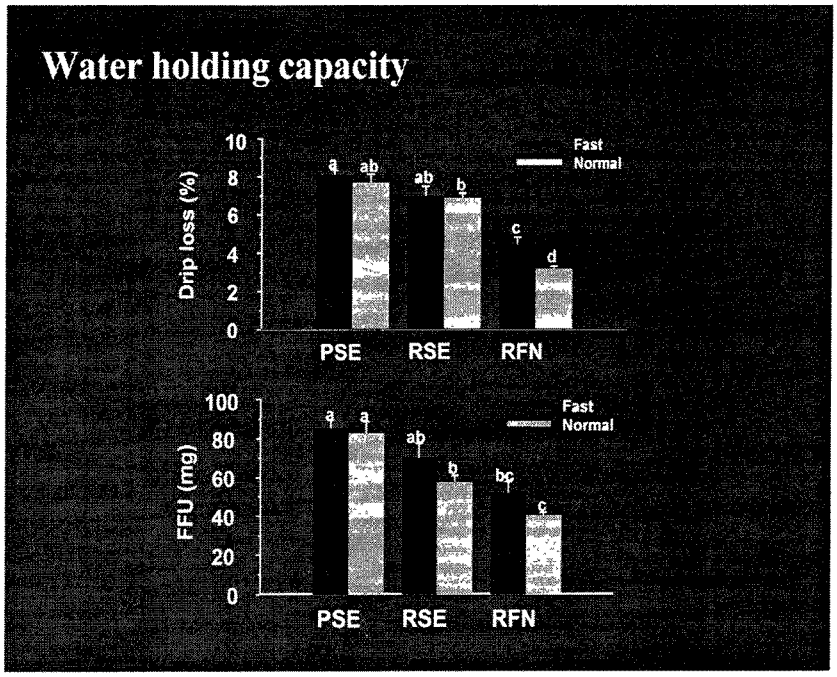
- **Muscle protein analyses**
  1. **Protein solubility:** Total-, Sarcoplasmic-, Myofibrillar protein
  2. **Sarcoplasmic protein SDS-PAGE**

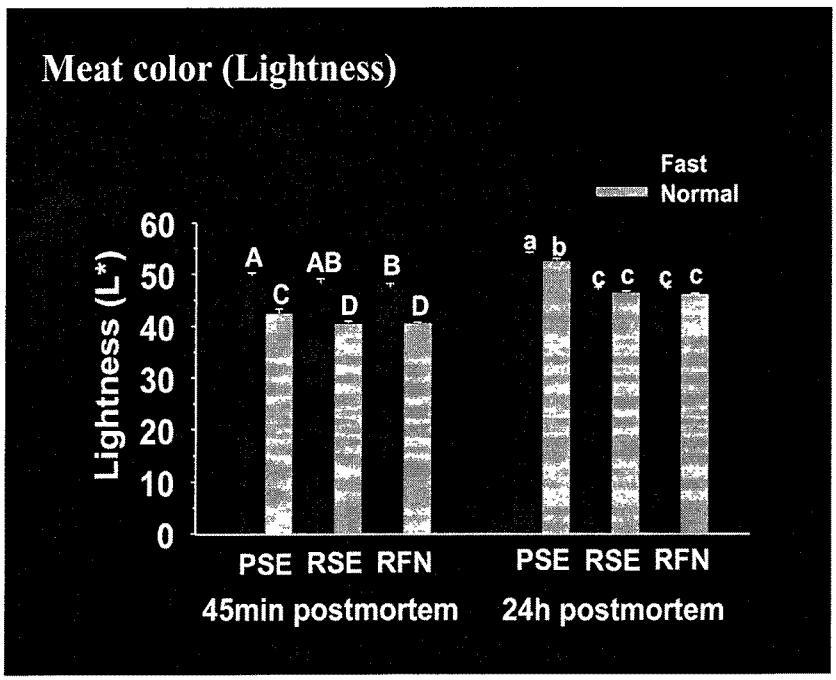


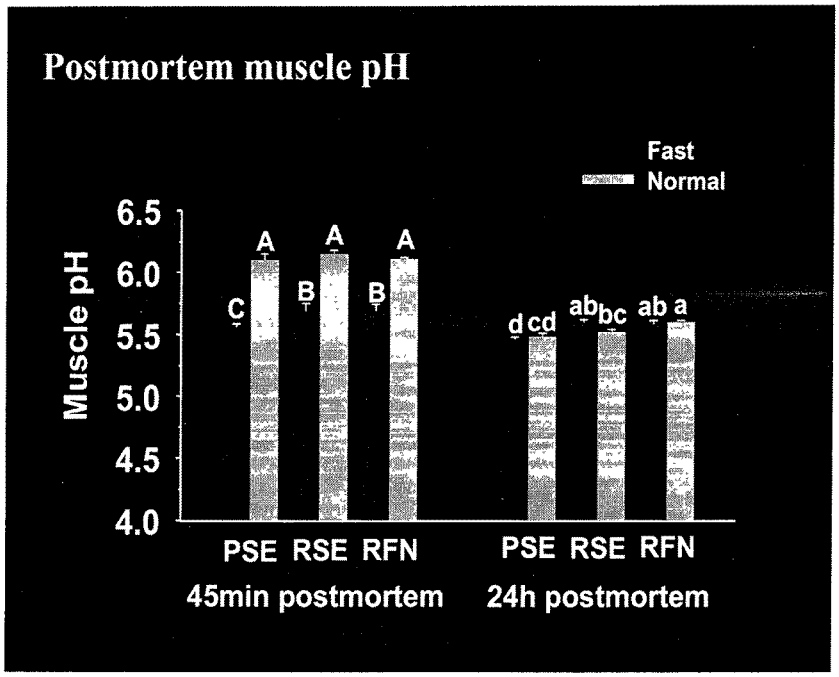
- **Metabolite concentration:** Glycogen, G-6-P, lactate, ATP

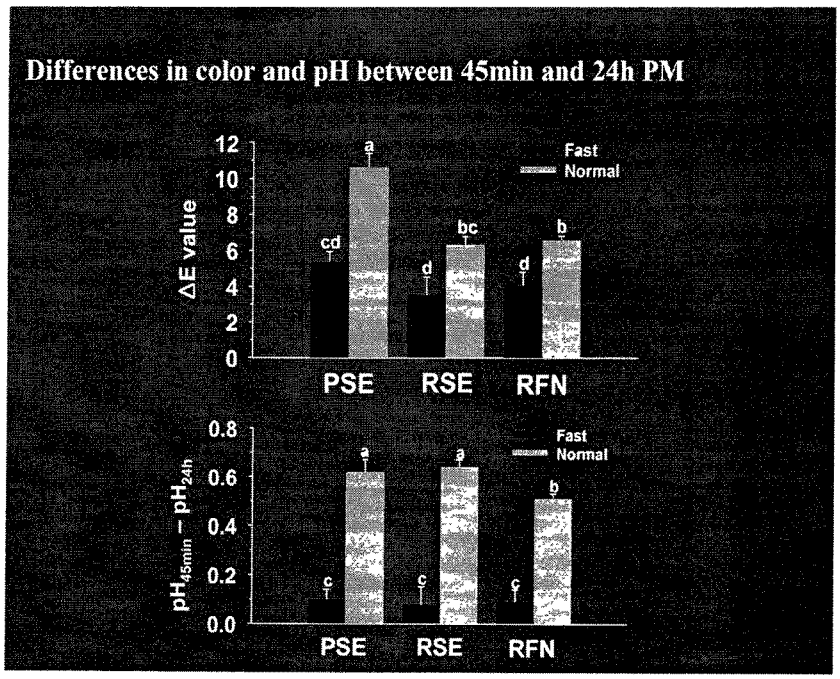
Results 1

Postmortem metabolic rate & Meat quality


Water holding capacity
Drip loss (%)
10
8
6
4
2
0
a
ab
ab
b
c
d
Fast
Normal
PSE
RSE
RFN
FFU (mg)
100
80
60
40
20
0
a
a
ab
b
bc
c
Fast
Normal
PSE
RSE
RFN

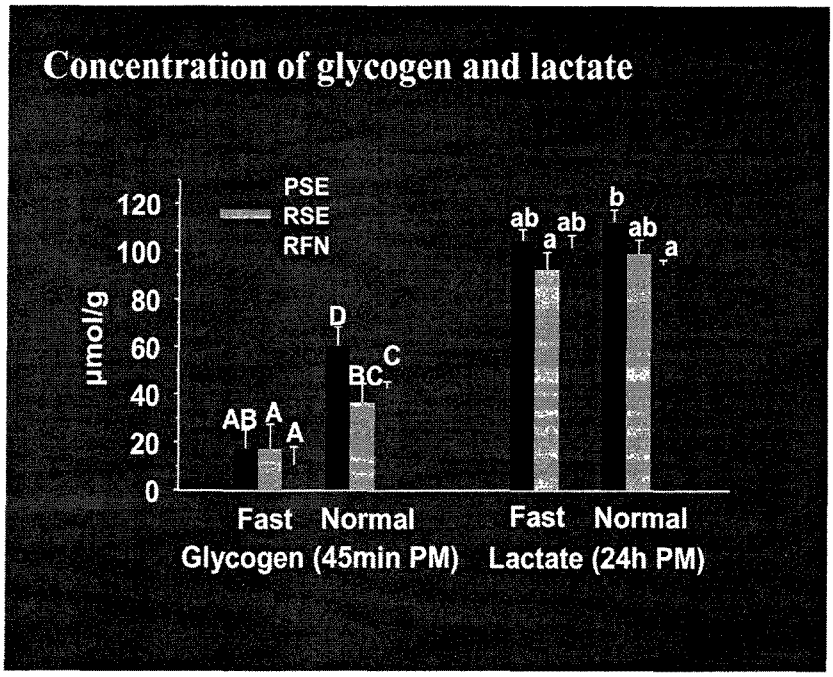

Meat color (Lightness)
Lightness (L*)
60
50
40
30
20
10
0
A
AB
B
C
D
D
a
b
c
c
c
c
Fast
Normal
PSE RSE RFN
PSE RSE RFN
45min postmortem
24h postmortem


Postmortem muscle pH
Fast
Normal
Muscle pH
6.5
6.0
5.5
5.0
4.5
4.0
C
A
B
A
B
A
d
cd
ab
bc
ab
a
PSE RSE RFN
PSE RSE RFN
45min postmortem
24h postmortem


Differences in color and pH between 45min and 24h PM
Fast
Normal
ΔE value
12
10
8
6
4
2
0
cd
a
d
bc
d
b
PSE RSE RFN
Fast
Normal
pH45min – pH24h
0.8
0.6
0.4
0.2
0.0
c
a
c
a
c
b
PSE RSE RFN

Results 2

Metabolite contents and Protein denaturation



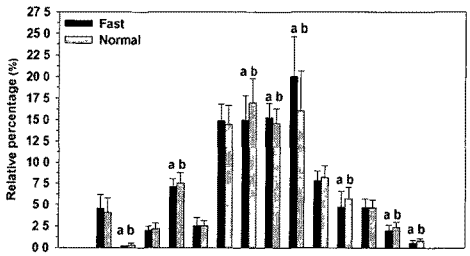
Protein solubility

	Fast			Normal		
	PSE	RSE	RFN	PSE	RSE	RFN
45 min postmortem						
TPS (mg/g)	161.19^{a}	186.64^{b}	190.38^{b}	205.89^{c}	217.39^{d}	216.99^{d}
MPS	101.41^{a}	113.09^{b}	122.86^{bc}	129.38^{cd}	136.29^{d}	135.41^{d}
SPS	67.77^{a}	73.55^{b}	67.52^{a}	76.51^{b}	81.11^{c}	81.59^{c}
24 h postmortem						
TPS	150.58^{a}	168.17^{b}	184.29^{c}	180.65^{bc}	189.65^{c}	197.06^{d}
MPS	90.91^{a}	104.40^{b}	116.80^{bc}	116.74^{bc}	120.04^{c}	125.05^{c}
SPS	59.84^{a}	63.70^{ab}	67.49^{bc}	63.91^{b}	69.62^{cd}	72.02^{d}

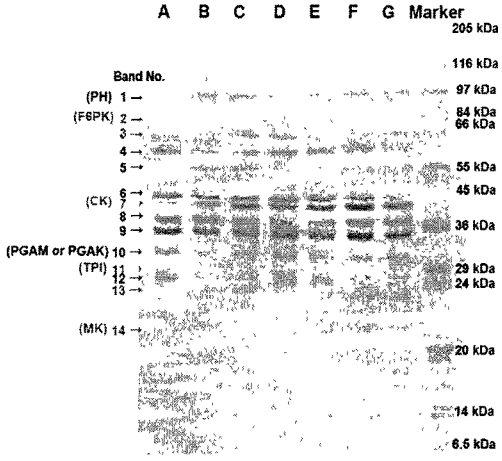
TPS, total protein solubility; MPS, myofibrillar protein solubility

SPS, sarcoplasmic protein solubility

Relative percentage of sarcoplasmic proteins



Sarcoplasmic protein SDS-PAGE



PH, phosphorylase b; F6PK, fructose-6-phosphate kinase; CK, creatine kinase; PGAM, phosphoglycerate mutase; PGAK, phosphoglycerate; TPI, triosephosphate isomerase; MK, myokinase

Results 3

Muscle histochemical analysis

Muscle fiber characteristics

	Fast			Normal		
	PSE	RSE	RFN	PSE	RSE	RFN
Cross-sectional area (μm^2)	3830	3968	4040	4052	3873	3958
Fiber density ($No./mm^2$)	264	257	261	252	265	261
Total fiber number ($\times 1,000$)	1278^{a}	1093^{b}	1184^{ab}	1103^{b}	1277^{a}	1181^{ab}

Fiber type composition

	Fast			Normal		
	PSE	RSE	RFN	PSE	RSE	RFN
Number percentage (%)						
Type I	5.28^{b}	5.89^{b}	7.42^{ab}	7.41^{ab}	7.61^{ab}	8.48^{a}
Type IIA	8.85^{b}	10.31^{ab}	13.32^{a}	12.28^{a}	11.23^{a}	12.41^{a}
Type IIB	86.00^{a}	83.80^{ab}	79.26^{cd}	80.31^{bcd}	81.16^{bc}	79.12^{d}
Area percentage (%)						
Type I	3.78^{c}	3.58^{c}	4.51^{bc}	5.40^{ab}	5.50^{ab}	5.93^{a}
Type IIA	4.69^{c}	5.02^{bc}	7.52^{a}	7.34^{a}	6.84^{ab}	7.36^{a}
Type IIB	91.53^{a}	91.40^{a}	87.97^{b}	87.26^{b}	87.66^{b}	86.71^{b}

Correlation coefficients between fiber type composition and meat quality traits

	Area percentage			Number percentage		
	Type I	Type IIA	Type IIB	Type I	Type IIA	Type IIB
TPS	.26^{z}	.32^{z}	−.41^{z}	.22^{y}	.27^{z}	−.37^{z}
MPS	.24^{z}	.22^{y}	−.32^{z}	.17^{x}	.18^{x}	−.27^{z}
SPS	.21^{y}	.40^{z}	−.44^{z}	.22^{y}	.35^{z}	−.43^{y}
pH_{45min}	.20^{y}	.20^{y}	−.33^{z}	.29^{z}	.13	−.31^{z}
pH_{24h}	−.02	.28^{z}	−.23^{y}	.09	.32^{z}	−.33^{z}
Drip loss	−.06	−.28^{z}	.36^{z}	−.25^{z}	−.26^{z}	.39^{z}
L*	−.18^{y}	−.23^{y}	.34^{z}	−.29^{z}	−.15^{x}	.33^{z}

$^{x}P < 0.05$, $^{y}P < 0.01$, $^{z}P < 0.001$

TPS, MPS, SPS : total-, myofibrillar- and sarcoplasmic protein solubility

Conclusion

Case	Metabolic property of muscle	Postmortem Metabolic rate	Quality classes	Type IIB % Area	Type IIB % No.	45 min PM Gly	45 min PM L*	45 min PM PS	24 h PM PD	24 h PM pH	24 h PM PS	Percentage
A	More glycolytic	Fast	PSE (17.3%)	√	√		√	√√√		√	√√√	69 2 (11 9)
B		Normal		√	√				√	√	√√	12 8 (2 2)
C	Less glycolytic					√			√	√	√√	18 0 (3 1)
D	More glycolytic	Fast	RSE (19.5%)	√	√		√	√√			√√√	18.2 (3.5)
E		Normal		√	√				√		√	25.0 (4.9)
F	Less glycolytic								√	√		56 8 (11.1)
G	More glycolytic	Fast	RFN (63.2%)	√				√				2.8 (1.8)
H		Normal		√				√				23 1 (14 6)
I	Less glycolytic	Fast										6 3 (4 0)
J		Normal										67 8 (42 9)

Gly, glycogen; L*, lightness; PS, Protein solubility; PD, pH difference

Conclusion

- Muscle histochemical characteristics influence early postmortem metabolic rate, the extent of glycolysis and thereby ultimate meat quality.
- Initial glycogen content and an extended duration of glycolysis can be used to explain the formation of late developing PSE.
- Undesirable pork may differ in structural proteins and/or in denaturation susceptibility as well as their accelerated glycolytic rate and an extended duration of glycolysis.

Summary