

Table 1 Traction, stretching and progressive tearing of *O. niloticus* (Nile tilapia) leathers tanned with chrome salts

Leathers		Thickness (mm)	Force (N)	Deformation (mm)	Stretching (%)	Traction (N mm⁻²)	Leather force (N)	Tearing (N mm⁻¹)
Head	Longitudinal	1.00±0.14 ^a	149.30±42.45 ^a	57.60±5.32 ^a	95.80±8.52 ^a	16.63±4.45 ^a	53.70±11.17 ^a	47.49±11.90 ^a
	Transversal	0.97±0.18 ^a	149.20±49.82 ^a	43.20±3.76 ^b	72.00±6.27 ^b	16.52±5.44 ^a	61.30±7.26 ^a	65.33±7.14 ^a
	Diagonal	0.99±0.12 ^a	89.00±21.11 ^c	32.40±6.09 ^c	54.00±10.07 ^c	9.99±2.76 ^a	64.30±21.67 ^a	72.16±24.58 ^a
Central	Longitudinal	0.93±0.15 ^a	106.70±32.57 ^{bc}	46.70±6.16 ^b	77.80±10.06 ^b	12.70±3.50 ^a	49.50±13.51 ^a	47.45±9.85 ^a
	Transversal	0.93±0.11 ^a	111.90±62.42 ^{bc}	34.30±5.20 ^c	57.20±8.50 ^c	13.59±7.66 ^a	58.80±18.27 ^a	66.10±18.40 ^a
	Diagonal	0.94±0.15 ^a	90.10±18.38 ^c	30.20±5.94 ^c	50.40±9.90 ^c	11.05±3.10 ^a	62.80±17.84 ^a	70.39±19.23 ^a
Tail	Longitudinal	1.04±0.16 ^a	134.40±26.71 ^{ab}	40.30±4.50 ^b	67.30±7.60 ^b	16.03±2.59 ^a	52.90±16.49 ^a	45.31±10.84 ^a
	Transversal	0.89±0.13 ^a	91.20±40.37 ^c	29.10±7.12 ^c	48.70±11.87 ^c	11.44±4.91 ^a	48.00±17.19 ^a	54.53±18.84 ^a
	Diagonal	0.92±0.14 ^a	110.10±54.58 ^{bc}	28.90±8.10 ^c	48.20±13.58 ^c	13.20±6.12 ^a	40.90±8.54 ^a	49.13±9.89 ^a
Main effects								
Regions								
Head		0.99±0.15 ^a	129.17±4.81 ^a	44.40±11.61 ^a	73.93±19.22 ^a	14.38±5.26 ^a	59.77±14.88 ^a	61.66±18.95 ^a
Central		0.93±0.14 ^a	102.90±41.62 ^a	37.07±9.05 ^a	61.80±14.99 ^a	12.45±5.11 ^a	57.03±17.06 ^a	61.31±18.78 ^a
Tail		0.95±0.16 ^a	111.90±44.45 ^a	32.77±8.47 ^a	54.73±14.16 ^a	13.56±4.99 ^a	47.27±14.96 ^b	49.65±13.84 ^b
Directions								
Longitudinal		1.00±0.15 ^a	130.13±37.84 ^a	48.20±8.92 ^a	80.30±14.66 ^a	15.12±3.89 ^a	52.03±13.54 ^a	46.79±10.56 ^b
Transversal		0.93±0.12 ^a	117.43±55.51 ^a	35.53±7.98 ^a	59.30±13.20 ^a	13.86±6.27 ^{ab}	56.03±15.69 ^a	61.98±16.12 ^a
Diagonal		0.95±0.16 ^a	96.40±35.57 ^a	30.50±6.70 ^a	50.87±11.18 ^a	11.41±4.34 ^b	56.00±19.63 ^a	63.89±21.12 ^a
Probabilities								
Region (R)		0.0085	0.0488	<0.0001	<0.0001	0.295	0.0058	0,0044
Direction (D)		0.003	0.0082	<0.0001	<0.0001	0.0122	0.513	<0,0001
Interaction R x D		0.0166	0.0337	0.0071	0.0075	0.06	0.0943	0.2414
C.V. ¹ (%)		14.67	36.01	15.57	15.47	35.53	28.07	28.07

Averages in the same column followed by standard deviation with different superscript letters are significantly different by Tukey's test ($p < 0.05$). ¹C.V.= Coefficient of variation.

Table 2 Traction, stretching and progressive tearing of *A. gigas* (paiche) leathers tanned with chrome salts

Leathers		Thickness (mm)	Force (N)	Deformation (mm)	Stretching (%)	Traction (N mm ⁻²)	Leather force (N)	Tearing (N mm ⁻¹)
Head	Longitudinal	2.67±0.34 ^a	284.60±153.61 ^a	30.40±5.85 ^a	50.60±9.39 ^a	10.31±6.01 ^a	105.40±21.82 ^a	42.11±9.94 ^a
	Transversal	2.77±0.55 ^a	131.20±55.29 ^a	40.40±12.42 ^a	67.40±20.50 ^a	5.16±2.52 ^a	81.40±14.58 ^a	32.16±4.80 ^a
	Diagonal	2.50±0.53 ^a	124.40±65.12 ^a	24.60±3.57 ^a	40.40±5.85 ^a	5.72±3.17 ^a	104.60±18.37 ^a	44.52±10.32 ^a
Central	Longitudinal	2.53±0.53 ^a	359.40±119.57 ^a	33.00±4.69 ^a	52.80±8.61 ^a	13.21±5.02 ^a	116.80±27.62 ^a	53.68±9.93 ^a
	Transversal	2.32±0.19 ^a	146.80±112.23 ^a	48.00±10.29 ^a	79.80±17.34 ^a	8.67±5.14 ^a	103.20±15.83 ^a	46.76±7.16 ^a
	Diagonal	2.31±0.41 ^a	229.40±86.43 ^a	33.40±7.70 ^a	57.20±13.64 ^a	10.87±3.39 ^a	113.80±27.67 ^a	54.76±13.97 ^a
Tail	Longitudinal	1.96±0.30 ^a	261.40±101.51 ^a	26.40±10.01 ^a	55.80±21.74 ^a	12.64±6.44	86.00±24.23 ^a	48.72±11.51 ^a
	Transversal	2.19±0.26 ^a	223.60±152.40 ^a	22.40±15.43 ^a	102.80±16.71 ^a	10.28±6.67 ^a	117.60±20.15 ^a	56.05±10.96 ^a
	Diagonal	2.11±0.24 ^a	256.20±65.37 ^a	24.40±3.84 ^a	55.80±12.19 ^a	10.33±0.71 ^a	108.20±34.81 ^a	49.43±18.79 ^a
Main effects								
Head		2.64±0.14 ^a	180.06±121.19 ^a	31.80±10.16ab	52.80±16.97c	7.07±4.55b	97.13±20.64 ^a	39.60±9.79b
Central		2.09±0.28c	245.20±134.24 ^a	38.13±10.28 ^a	63.27±17.61b	10.91±4.66 ^a	111.27±23.34 ^a	51.74±10.58 ^a
Tail		2.39±0.41b	247.06±105.36 ^a	24.40±10.19b	71.47±27.99 ^a	11.09±5.10 ^a	103.93±28.61 ^a	51.40±13.59 ^a
Directions								
Longitudinal		2.40±0.49 ^a	301.80±125.07 ^a	29.93±7.25b	53.07±13.65b	12.05±5.57a	102.73±26.36 ^a	48.17±10.88 ^a
Transversal		2.42±0.43 ^a	167.20±113.38c	36.93±16.30 ^a	83.33±22.72 ^a	8.04±5.19b	100.73±22.04 ^a	44.99±12.61 ^a
Diagonal		2.30±0.43 ^a	203.33±89.63b	27.47±6.61b	51.13±12.94b	8.97±3.46b	108.87±26.02 ^a	49.57±14.35 ^a
Probabilities								
Region (R)		<0.0001	0.1632	0.0009	0.0061	0.0428	0.2731	0.0084
Direction (D)		0.2286	0.0043	0.0197	<0.0001	0.0451	0.6204	0.5378
Interaction R x D		0.0581	0.3225	0.1038	0.1657	0.9421	0.1148	0.3381
C.V. ¹ (%)		16.5	47.74	28.87	23.87	48.9	22.67	24.05

Averages in the same column followed by standard deviation with different superscript letters are significantly different by Tukey's test ($p < 0.05$). ¹C.V.= Coefficient of variation.

Table 3 Traction, stretching and progressive tearing of *C. virescens* (croaker) leathers tanned with chrome salts

Leathers		Thickness (mm)	Force (N)	Deformation (mm)	Stretching (%)	Traction (N mm ⁻²)	Leather force (N)	Tearing (N mm ⁻¹)
Head	Longitudinal	0.85±0.16 a	73.16±19.25c	41.00±6.00a	68.66±10.44a	8.73±2.47c	42.10±57.83a	57.83±33.40 a
	Transversal	0.75±0.13a	78.83±38.31c	68.50±10.59a	114.16±17.23a	11.66±5.35bc	42.13±62.00a	62.33±20.40a
	Diagonal	0.85±0.21a	54.16±28.38d	37.83±9.62a	63.16±16.26a	7.38±3.90c	22.61±49.16a	49.16±15.76a
Central	Longitudinal	0.94±0.28a	158.50±77.10b	36.16±6.11a	60.50±10.13a	18.08±8.92b	119.63±55.75a	96.16±56.50a
	Transversal	0.82±0.17a	102.00±34.72c	75.66±14.12a	126.33±23.16a	13.05±3.86bc	84.25±19.02a	67.33±19.08a
	Diagonal	0.90±0.24a	60.33±49.47cd	43.16±11.10a	72.00±18.37a	7.87±6.42c	99.67±32.69a	89.83±26.14a
Tail	Longitudinal	0.94±0.28a	333.50±70.33a	36.16±3.18a	60.00±5.40a	25.12±5.44a	59.08±15.57a	79.16±26.70a
	Transversal	0.82±0.17a	135.50±32.67bc	61.16±16.47a	102.00±27.48a	14.59±5.41bc	227.19±380.03a	85.66±20.56a
	Diagonal	0.94±0.28a	139.33±49.55bc	27.33±6.74a	45.33±11.00a	13.50±5.12bc	81.45±17.94a	69.50±19.07a
Main effects								
Regions								
Head		0.81±0.17a	68.72±29.92a	49.11±16.48ab	82.00±27.39ab	9.26±4.25a	56.44±23.56b	73.90±35.03a
Central		0.88±0.25a	106.94±67.35a	51.66±20.48a	86.27±34.06a	13.00±7.63a	84.44±37.54a	101.18±39.46a
Tail		1.13±0.27a	202.77±107.4 2a	41.55±17.70b	69.11±29.61b	17.74±7.35a	78.11±22.08ab	122.57±220.28a
Directions								
Longitudinal		1.03±0.30a	188.38±125.48a	37.77±5.48b	63.05±9.35b	17.31±9.03a	77.72±41.68a	84.24±47.00a
Transversal		0.79±0.15a	105.44±40.90a	68.44±14.44a	114.16±23.91a	13.10±4.79a	71.77±21.46a	130.73±219.16a
Diagonal		0.93±22a	84.61±57.19a	36.11±11.67b	60.16±18.51b	9.59±5.70a	69.50±25.94a	82.68±27.37a
Probabilities								
Region (R)		<0.0001	<0.0001	0.0126	0.0104	<0.0001	0.0147	0.5384
Direction (D)		<0.0001	<0.0001	<0.0001	<0.0001	0.0005	0.6806	0.4618
Interaction R x D		0.0041	<0.0001	0.3111	0.3101	0.0425	0.403	0.3519
C.V. ¹ (%)		23.03	38.03	21.4	21.28	41.15	39.6	13.61

Averages in the same column followed by standard deviation with different superscript letters are significantly different by Tukey's test ($p < 0.05$). ¹C.V.= Coefficient of variation.

Table 4 Traction, stretching and progressive tearing of *O. niloticus* (Nile tilapia), *C. virescens* (croaker) and *A. gigas* (paiche) leathers tanned with chromium and tannin salts

Leathers		Thickness (mm)	Force (N)	Deformation (mm)	Stretching (%)	Traction (N mm ⁻²)	Leather force (N)	Tearing (N mm ⁻¹)
<i>O. niloticus</i>	Chromium salts	0.90±0.14 ^a	118.52±44.68 ^a	42.86±10.69 ^b	71.40±17.68 ^a	13.45±4.65 ^a	59.15±14.04 ^a	61.17±17.02 ^a
	Vegetable tannin	1.01±0.13 ^a	152.25±65.41 ^a	41.81±11.74 ^b	69.65±19.69 ^a	14.91±5.90 ^a	69.31±26.28 ^a	68.11±25.14 ^a
<i>C. virescens</i>	Chromium salts	0.90±0.27 ^a	122.97±101.47 ^a	49.13±18.04 ^a	82.00±30.07 ^a	13.31±7.95 ^a	71.90±32.17 ^a	104.56±43.42 ^a
	Vegetable tannin	1.00±0.25 ^a	147.95±116.66 ^a	43.91±18.08 ^{ab}	73.18±30.30 ^a	13.28±8.73 ^a	92.13±44.13 ^a	101.06±47.73 ^a
<i>A. gigas</i>	Chromium salts	2.31±0.41 ^a	220.88±121.66 ^a	31.47±11.60 ^c	62.81±22.50 ^a	9.66±5.08 ^a	104.52±24.69 ^a	48.03±12.31 ^a
	Vegetable tannin	2.44±0.49 ^a	268.50±120.83 ^a	40.61±14.26 ^b	67.70±23.76 ^a	11.20±5.27 ^a	106.36±23.09 ^a	45.63±11.93 ^a
Mains effects								
Fishes	<i>O. niloticus</i>	0.96±0.15 ^b	135.38±58.21 ^b	42.34±11.17 ^a	70.59±18.62 ^{ab}	14.18±5.34 ^a	64.23±21.56 ^c	64.64±21.63 ^b
	<i>C. virescens</i>	0.95±0.27 ^b	135.46±61.23 ^b	46.52±18.15 ^a	77.59±30.33 ^a	13.30±8.30 ^a	82.02±39.72 ^b	102.81±66.28 ^a
	<i>A. gigas</i>	2.38±0.45 ^a	244.69±122.90 ^a	36.06±13.72 ^a	65.26±23.14 ^b	10.43±5.20 ^b	105.44±23.79 ^a	46.83±12.11 ^c
Tanning agents	Chromium salts	1.23±0.63 ^a	154.12±105.55 ^b	41.15±15.57 ^a	72.07±25.05 ^{ab}	12.14±6.28 ^{ab}	78.53±31.18 ^b	71.25±86.51 ^{ab}
	Vegetable tannin	1.35±0.68 ^b	189.56±117.56 ^a	42.11±14.87 ^a	70.18±24.88 ^{ab}	13.13±6.92 ^{ab}	89.27±35.72 ^a	71.60±39.04 ^{ab}
Probabilities								
Fishes (F)		<0.0001	<0.0001	<0.0001	0.0041	0.0004	<0.0001	<0.0001
Tanning agents (T)		<0.0001	0.004	0.5906	0.5301	0.2128	0.0028	0.9644
Interaction F x T		0.9645	0.7497	0.0035	0.1802	0.6643	0.1095	0.8349
C.V. ¹ (%)		21.52	38.01	34.57	34.4	51.06	34.45	38.65

Averages in the same column followed by standard deviation with different superscript letters are significantly different by Tukey's test ($p < 0.05$). ¹C.V.= Coefficient of variation.

Table 5 Physicochemical analysis of *O. niloticus* (Nile tilapia), *C. virescens* (croaker) and *A. gigas* (paiche) leathers tanned with chromium salts and vegetable tannin

Leathers		Content of substance evaluated (%)			pH
Species	Tanning agents	Calcium	Chromium oxide	ESD ¹	
<i>O. niloticus</i>	Chromium salts	0.05	3.11	15.64	3.77
	Vegetable tannin	0.15	NF ²	11.84	5.43
<i>C. virescens</i>	Chromium salts	0.08	2.83	21.97	3.9
	Vegetable tannin	0.54	NF	15.24	5.53
<i>A. gigas</i>	Chromium salts	0.09	2.94	25.1	4.2
	Vegetable tannin	0.1	NF	17.51	5.49

¹ESD, extractable substances in dichloromethane.

²NF, not found