

Table 1. Performance of captive bolt stunners that could be appropriate for pig culling according to their type and power source.

Captive bolt stunner type	Power source and nominal powerload	Bolt weight (g)	Muzzle bolt Length x Width (mm)	Velocity peak (ms ⁻¹)	Velocity range (ms ⁻¹)	Kinetic energy peak (J)	Reference
SAT ¹	1.0 gr ^{×†}	179	- x 25	29	19 - 31	76	Gibson et al. 2018
SAT ¹	1.0 gr [†]	179	-	-	-	47 [#]	Grist et al. 2019
SAT ¹	1.25 gr [†]	179	25-35 x -	-	-	107	Grist et al. 2018c
TED ²	Propane fuel cell	61	- x 10	30	25 - 31	28	Gibson et al. 2018
TED ²	Propane fuel cell	70	5-10 x 10	-	-	30	Anon 2016
Zephyr-EXL	827 kPa (120 psi) [‡]	69		27	14 - 28	24	Gibson et al. 2018
Zephyr-EXL	827 kPa (120 psi) [‡]	69	-	-	-	28	Grist et al. 2017
Dick KTBG	Spring	120	30 x 5	9	8 - 13	5	Sharp et al. 2015
Finito 244	Spring	102	33 x 5	9	8 - 9	4	Sharp et al. 2015
.22 Cash Special	1.0 gr [†]	211	63 x 11	30	24 - 35	97	Gibson et al. 2015b
.22 Cash Special	1.25 gr [†]	211	68 x 11	45	41 - 46	210	Gibson et al. 2015b
.22 Cash Special	2.5 gr [†]	211	72 x 11	48	48 - 48	241	Gibson et al. 2015b
.22 Cash Special	3.0 gr	211	73 x 11	53	51 - 54	292	Gibson et al. 2015b
.22 Cash Special*	5 gr [†]	211	-	69	68 - 71	496	Unpublished ³
.22 CTrade TEC 10*	4 gr [†]	182	-	72	67 - 77	464	Unpublished ³
.22 GiL Umana*	3 gr [†]	180	80 x 10	90	80 - 123	733	Dalla Costa et al. 2016
.22 GiL Umana*	4 gr [†]	180	80 x 10	81	66 - 128	613	Dalla Costa et al. 2016
.22 GiL Umana*	5 gr [†]	180	80 x 10	94	76 - 117	796	Dalla Costa et al. 2016

[×]gr: grain

*This gun could be effective for dispatching finishing and breeding pigs

[#] Note: this result was generated from the firing of a projectile against gravity with a one-point velocity recording.

[†] Propellant: nitrocellulose

[‡] Propellant: compressed air

¹ SAT: Cash Poultry Killer

²TED: Turkey Euthanasia Device

³Unpublished data from authors' database

Table 2. Performance of free bullet rifles that could be appropriate for pig culling according to their type, ammunition and species.

Gun type	Bullet, ammunition, grain	Distance of shooting (m)	Shot position (head)	Velocity ¹ (ms-1)	Kinetic Energy ¹ (J)	Specie	Effectiveness ²	Reference
.22 Long rifle	Copper plate hollow point, 40 gr, 2.6 g	2	Frontal	-	-	Horse	100% (46/46) ^a	Gibson et al. 2015a
.22 Rifle, Ruger 10/22	Remington standard and high velocity, 40 gr	25	Frontal	350 and 382, respectively	-	Cattle	0% (0/2) ^b	Hugh et al. 1995
.22 Rifle, Ruger 10/22	Omark shotshell	0.1 or 2	Frontal	-	-	Cattle	0% (0/2) ^b	Hugh et al. 1995
.223 Rifle, Ruger Mini-14	American eagle full metal jacket, 55 gr and Core-Shot prefragmented ammunition	25	Frontal	853	-	Cattle	100% (4/4) ^b	Hugh et al. 1995
.30-06 Rifle, Remington Model 721	Gevelot softnose, 180 gr	25	Frontal	823	-	Cattle	100% (2/2) ^b	Hugh et al. 1995
9.3 x 62 Long rifle	9.3 mm diameter - part fragmenting bullet, 18.5 g	1	Frontal	695-600	4,470-3,360	Cattle	100% (4/4) ^b	Schiffer et al. 2014
.30-06 bionic yellow Long rifle	7.6 mm diameter - part fragmenting bullet and deformation bullet, 10 g	1	Frontal	885-760	3,915-2,880	Cattle	100% (11/11) ^b	Schiffer et al. 2014
.30-06 bionic black Long rifle	7.6 mm diameter - deformation bullet, 10 g	1	Lateral	885-760	3,915-2,880	Cattle	33.33% (2/6) ^b	Schiffer et al. 2014

.30-06 Barnes Long rifle	7.6 mm diameter - deformation bullet, 10.9 g	1	Frontal	885-790	3,940-3,360	Cattle	100% (2/2) ^b	Schiffer et al. 2014
.22 Hornet Long rifle	5.6 mm - part fragmenting bullet, 2.9 g	1	Frontal	770-550	865-460	Cattle	100% (5/5) ^b	Schiffer et al. 2014
.22 Hornet Long rifle	5.6 mm - part fragmenting bullet, 2.9 g	1	Lateral	770-550	865-460	Cattle	40% (2/5) ^b	Schiffer et al. 2014
.22 Magnum Long rifle	5.6 mm - part fragmenting bullet, 2.6 g	1	Frontal	580-400	440-210	Cattle	100% (4/4) ^b	Schiffer et al. 2014
.22 Long rifle - Semiautomatic rimfire rifle	Plated lead solid, 30 gr	3	Frontal	-	217	Cattle	100% (6/6) ^b	Thomson et al. 2013
.22 Long rifle - Semiautomatic rimfire rifle	Hollow-point round, 30 gr	3	Frontal	-	219	Cattle	50% (3/6) ^b	Thomson et al. 2013
.223-caliber Carbine Semiautomatic	Ballistic-tip round, 50 grain	3	Frontal	-	1,604	Cattle	100% (6/6) ^b	Thomson et al. 2013
.22 Firearm, Weapon recommended for euthanasia (Winchester)	High velocity round-nosed bullet (Superspeed) and Hollow-point bullet (Subsonic)	3	Lateral (Temporal bone)	-	-	Sheep	100% (20/20) ^b	Finnie 1993

¹ Peak or Range of velocity or kinetic energy.

² Effectiveness was evaluated in live animals or cadavers (head only)

^a Live animal

^b Head only – carcass model

Table 3. Performance of free bullet shotguns that could be appropriate for pig culling according to their type and ammunition.

Gun type	Bullet, ammunition, grain	Distance of shooting (m)	Shot position (head)	Velocity ¹ (ms ⁻¹)	Kinetic Energy ¹ (J)	Species	Effectiveness ²	Reference
12 gauge pump action Shotgun, Remington 870	Winchester 1 oz rifled slug	25	Frontal	-	-	Cattle	0% (0/1) ^b	Hugh et al. 1995
12 gauge pump action Shotgun, Remington 870	Remington #7 1/2 birdshot	2	Frontal	-	-	Cattle	100% (1/1) ^b	Hugh et al. 1995
12 gauge shotgun, Velpa	1 1/4 oz rifled slug	25	Frontal	-	-	Cattle	100% (1/1) ^b	Hugh et al. 1995
12-gauge shotgun	2.75-inch 1.25-ounce No. 4 birdshot shell	3	Frontal	-	2,398	Cattle	100% (6/6) ^b	Thomson et al. 2013
12-gauge shotgun	1-ounce rifled slug	3	Frontal	-	5,552	Cattle	100% (6/6) ^b	Thomson et al. 2013
12-gauge single barrel - 1. choke shotgun	Single 28 g rifled lead slug (Winchester Super XI oz), 28 g	1.5		488	3,334	Bull	100% (1/1) ^b	Blackmore 1995
12-gauge single barrel - 1. choke shotgun	Nine individual lead pellets (buckshot) 8.33 mm in diameter with a combined mass of 28 g (Winchester OO/SG), 28 g	0.6		401	2,251	Sow	100% (2/2) ^b	Blackmore 1995
12-gauge single barrel - 1. choke shotgun	Single 28 g rifled lead slug (Winchester Super XI oz)	0.6	From the back (occipital)	401	2,251	Boar	0% (0/1) ^b	Blackmore 1995

12-gauge single barrel - 1. choke shotgun	Single 28 g rifled lead slug (Winchester Super XI oz)	0.6	Frontal	488	3,334	Boar	100% (1/1) ^b	Blackmore 1995
12-gauge single barrel - 1. choke shotgun	Single 28 g rifled lead slug (Winchester Super XI oz)	0.6	Lateral (Behind the ear)	488	3,334	Boar	100% (1/1) ^b	Blackmore 1995
12-gauge single barrel - 1. choke shotgun	Nine individual lead pellets (buckshot) 8.33 mm in diameter with a combined mass of 28 g (Winchester OO/SG)	0.6	Lateral (Behind the ear)	401	2,251	Boar	100% (1/1) ^b	Blackmore 1995
12-gauge single barrel - 1. choke shotgun	Nine individual lead pellets (buckshot) 8.33 mm in diameter with a combined mass of 28 g (Winchester OO/SG)	0.3	Lateral (Behind the ear)	401	2,251	Saw	100% (1/1) ^a	Blackmore 1995

¹ Peak or Range of velocity or kinetic energy.

² Effectiveness was evaluated in live animals for stunning and killing or in cadavers as capacity of penetration in the head

^a Live animal

^b Head only

Table 6. Electrophysiological and pathology findings of piglets exposed to different pressures and ascension rates.

Pressure (kPa)	Altitude (m)	Ascension rate (m/sec)	Electrophysiology and pathology findings	Animal description	N	Reference
19.36	11,600	36.9 m/sec	The electroencephalogram data were consistent with drowsiness and dizziness states.	Nursery piglets	5	Eagle and Edwards 2010
19.36	11,600	36.9 m/sec	Higher percent haematocrit, haemoglobin concentration, sodium, blood lactate concentration, and pH for piglets culled using LAPs than CO ₂ system.	Nursery piglets	26	Eagle and Edwards 2010
19.36	11,600	36.9 m/sec	Lower pCO ₂ , iCa and potassium for piglets culled using LAPs than CO ₂ system.	Nursery piglets	26	Eagle and Edwards 2010
19.36	11,600	36.9 m/sec	Pulmonary lesions, such as: partial atelectasis or partially collapsed lungs and severe pulmonary oedema of the majority of the lungs, which were related to the culling procedures were found 21% of piglets.	Nursery piglets	26	Eagle and Edwards 2010
19.36	11,600	36.9 m/sec	One pig culled had diffuse emphysema of the subcutaneous tissues which appeared as small clear air bubbles in the fat and fascia of the subcutis.	Nursery piglets	26	Eagle and Edwards 2010
19.36	11,600	36.9 m/sec	One pig had a small amount of mucoid exudate in the nasal passages.	Nursery piglets	26	Eagle and Edwards 2010
6.6	18,000	36.9 m/sec	Time to onset of respiratory distress using low atmosphere pressure system was 8.9 ± 3.8 min	Nursery piglets (5.6 ± 1.3 kg; 21-28 d)	29	Eagle and Edwards 2010
6.6	18,000	36.9 m/sec	The average time to reach the point of a completely isoelectric state was 27.4 ± 6.7 minute.	Nursery piglets (5.6 ± 1.3 kg; 21-28 d)	29	Buzzard 2012

Table 7. Summary of the advantages and disadvantages of different on-farm culling methods for piglets and pigs (when correctly performance).

Methods / Variables	Blunt force trauma				Controlled atmosphere			Electrocution device	
	Mechanical		Manual		Gas culling		LAPS ²	Homemade	Commercial
	CBS ¹ - pneumatic	CBS ¹ - cartridge	With a solid object	Against a solid surface	Gradual filling administration	High concentration			
<i>Animal</i>									
Instantaneous unconsciousness	Yes	Yes	Yes	Yes	No	No	No	Variable	Yes
Risk of consciousness recovery	No	No	Moderate	Moderate	Low	Low	Low	Yes	No
Risk of failure	Low	Low	Moderate	Moderate	Low	Low	Low	High	Low
Potential for pain and distress ³	Low	Low	Moderate	Moderate	Moderate	High	Low-Moderate	High	Low
Apparent brain damage	High	High	Moderate	Moderate	No	No	No	No	No
Need to be restrained ⁴	Moderate	Moderate	Moderate	High	Low	Low	Low	Moderate	Moderate
Presence of seizure	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
<i>Operator and device</i>									
Safety system	Yes	Yes	N/A	N/A	Yes	Yes	Yes	No	Yes
Mobility ⁵	Moderate	High	High	High	Low	Low	Low	Moderate	Moderate
Accident risk	Low	Low	Low	Low	Low	Low	Low	High	Low
Need for training	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Accepted by legislation	Yes	Yes	Variable ⁶	Variable ⁶	Yes	Yes	For poultry ⁷	No	Yes
Potential public interpretation	Accepted	Accepted	Aesthetically unpleasant	Aesthetically unpleasant	Aesthetically unpleasant	Aesthetically unpleasant	Aesthetically unpleasant	Accepted	Accepted

¹CBS: Captive bolt stunner.

²LAPS: Low atmosphere stunning.

³Low: Instantaneously unconsciousness, no/low risk of consciousness recovery, failure and high repeatability, high brain damage; Moderate: potential lower repeatability associated to manual force application, method can fail and animals do not become instantaneously unconsciousness; High: animal shows aversion reflexes, the method do not cause instantaneously unconsciousness and/or brain damage.

⁴Low: partially restrain animal movements; Moderate: partially restrain the movements of the animal and its head; High: completely restrain/hold the movements of the animal and its head.

⁵Low: reasonable size, usually installed in a room, and needs cables or connections to power source; Moderate: small size and ease to transport, but needs cables or connections to power source; High: small size, ease to transport and there is no cables or connections to power source.

⁶The acceptance vary according to countries' legislation.

⁷There are little scientific information available using low atmosphere pressure for culling pigs.