

# Legislation and Practices in Israel for Protection of Pigs from Unnecessary Pain: Euthanasia in Pig Farming

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## ABSTRACT

Since 2012, pig farming in Israel started to be regulated for minimal standards for pig protection. In September 2012, the “Guidelines for Pig Farming”, were issued by the Veterinary Services of Ministry of Agriculture of the State of Israel. This was replaced by the “Regulations against cruelty to animals” (Protection of Animals) (Pigs Farming for Agricultural Purposes) on May 2015, issued by the same Ministry after approval by a special Commission of the Israeli Parliament. Among other aspects, current legislation deals with a problematic aspect relative to pig farming: accomplishment of euthanasia or emergency killing. The purpose of several articles of the current regulations, was to minimize or avoid unnecessary pain and sufferance in pigs, caused by injuries or diseases or any other traumatic events. This article examines practical implications of euthanasia or emergency killing of pigs at the farm level, and addresses solutions for consideration in the local pig industry.

**Key words:** Israel; Pig Farming; Regulations; Mutilations; Euthanasia.

## INTRODUCTION

### Characteristics of swine farming in Israel

In Israel, pig production is limited to 25 farms that produce approximately 170,000-200,000 pigs per year. The farms are located in three well defined areas in the Country. Specifically, one farm is located in the Negev District (Kibbutz Lahav), with around 1,000 sows and 19,000-20,000 pigs produced per year, while the other 24 farms are situated in the Northern District (1 farm in Fassuta, 23 farms in Ibbilin), with a production of 150,000-180,000 pigs per year. In addition, there is another farm of 30 Sinclair (minipig) sows in Lower Galilee District (Yokneam) that produces purpose-bred laboratory pigs, not for human consumption. Out of 23 farms located in Ibbilin area, 16 are in close contact, sharing dividing walls, service road, water distribution, manure collection. Three other farms, share personnel, owners, semen for artificial insemination, etc. These facts contribute in making Ibbilin

farms a unique epidemiological unit. The number of sows is around 15,000, of Landrace, Large-White, Pietrain, Duroc breeds, and their cross-breeding; genetic material (semen for artificial insemination) is recurrently imported from Cyprus, Germany and France.

Pig farming in Israel is regulated, like other livestock farming, and the relevant legislation dealing with protection of pigs farmed for agriculture purposes is indicated in Table 1.

This article deals with euthanasia, or emergency killing of pigs, at the farm level.

Situations such as slow growth, wasting diseases, illness, injuries, which make unprofitable keeping a pig, or an animal suffering and unable to be transported for slaughter, requiring humane euthanasia, or emergency killing, on-farm thus avoiding transportation to the slaughterhouse due to stress and pain possibly induced by transportation.



**Figure 1:** Painful, adverse and unrecoverable clinical situations

Any pig that is in continuous pain, or failing to respond to treatment, should be humanely euthanized as soon as possible. Examples of situations in which euthanasia should be performed are: evident pain without relief; “paddling” (lying on the side with continuous legs movements) as in neurological diseases; uterus and/or badly damaged vagina prolapses; lacerated abdominal/umbilical hernias; anal atresia; blocked farrowing; severe arthritis with swollen and painful joints; broken legs or hip joints (so that pig cannot stand and/or walk); severe wounds (flank biting at advanced stage; tail biting at advanced stage with hind legs impairment; etc.); pigs not responding to medical treatment; runts/thin pigs not improving with treatments. Figure 1

shows some common adverse and painful situations in pig farms.

The “Procedure: Treatment of a down animal in the farm”, update 2, 2018 (1) issued by The Israel Veterinary Services requires that down animals (cattle, small ruminants, pigs) should be identified, properly isolated (as, for example in pigs, according to Regulations, Art.19) within 24 hours and receive a veterinary visit/treatment within next 12 hours. Because transportation of down animals is forbidden, according to at Art.6, of the above “Regulations against cruelty in animals (Protection of Animals) (Transportation of livestock)”, 2006, down animals should be euthanized either according to Veterinarian opinion or within five days.

**Table 1:** Israeli legislation dealing with pig protection

Law against cruelty in animals (Protection of Animal Raised for Agricultural Purposes), 1994	חוק צער בעלי חיים (גידול בעלי חיים לצרכים חקלאיים), 1994
Regulations against cruelty in animals (Protection of Animals) (Pigs Farming for Agricultural Purposes), 2015	תקנות צער בעלי חיים (הגנה על בעלי חיים) (גידול חזירים והחזקתם לצרכים חקלאיים), 2015
Livestock Diseases Ordinance, 1985	פקודת מחלות בעלי חיים, 1985
Regulations against cruelty in animals (Protection of Animals) (Transportation of livestock), 2006	תקנות צער בעלי חיים (הגנה על בעלי חיים) (הובלת בהמות), 2006

Relative to some specific and relatively diffused pig diseases (e.g. neurological forms from *S. suis* or *E. coli*; severe tail lesions with hind legs paralysis; rectal or uterine/vaginal prolapse; anatomical malformations; etc), authors believe that a waiting period of five days is too long and animals should be put down immediately, as an irreversible diagnosis has been pronounced by the Veterinarian. Specific trainings for animal keepers, will help in promptly recognizing irreversible clinical or anatomical cases, and further contribute to spare unnecessary pain in animals. Random, or planned, Veterinary Services inspections at farm level should carefully investigate the appropriate veterinary intervention, timing and appropriate euthanasia technique. If necessary, even through gross-pathology examination. Farmers should be adequately educated to identify the need for immediate interventions relating to irreversibly ill or down animals.

Euthanasia can be performed pharmacologically, mechanically and/or by bleeding after stunning.

### Pharmacological euthanasia

A Veterinarian performs the procedure with euthanasia drugs, with dosages specifically indicated for this purpose. Most specific veterinary euthanasic drugs must be used intravenously only (IV), which maybe difficult to apply in pigs under farm conditions. IV injections should be carried out on unconscious (pre-anesthetized) animals, or on restrained animals. According to the size of the animal, a moderate (handy) to severe (hog-snore) restraint is required for IV injections in pigs, which may also contribute to distress of the animal. All these factors make injectable euthanasic drugs difficult to apply, stressful, not practical and even uneconomic.

At least three veterinary euthanasic drugs are registered in Israel for use in different animal species, including pigs: Tanax-T61 (combination of: Embutramide 200 mg/ml, Mebenzonium 50 mg/ml, Tetracaine Hydrochloride 5 mg/ml) and Pentobarbital Sodium 500 mg/ml; Pentobarbital Sodium 200 mg/ml (2). Mebenzonium is also registered as Mebozonium).

- Embutramide: is a general anesthetic, with a strong narcotic effect inducing severe depression of Central Nervous System (CNS), hypoxia, and circulatory collapse (3); paralyzes the brain centers controlling breathing in the central nervous system.
- Mebenzonium: has a curariform-like action; it paralyzes

the skeletal muscles, induces paralysis of intercostal muscles and of the diaphragm, with respiratory collapse.

- Tetracaine hydrochloride: it has local anesthetic activity, reducing painful tissue reactions at the injection site.
- Pentobarbital sodium: is a depressant of CNS; depress neuronal activity, smooth, skeletal and myocardial muscles activity, inducing cardiovascular collapse. Overdose, like other barbital derivatives, induces deep anesthesia, with induction of apnea due to depression of the respiratory center, followed by cardiac arrest.

Injections should be intravenous (IV); or intracardiac (IC) to make sure that death is rapid. Barbiturates may not cause death if not administered IV (4). Both drugs may be difficult to implement at farm level, and requires a high competence. Pentobarbital is not inactivated by (boiling) temperature or by decomposition, and there are concerns relative to possible pollution of soil and water (4).

In pigs, the ear veins are the most commonly used for IV injections. IC administration causes high blood concentrations, but in conscious animals may be extremely painful if penetration of the heart is not achieved at the first attempt (5), therefore, making prior anesthesia a requirement.

When using Tanax-T61, concerns are that the paralytic effect of Mebenzonium, like other curariform drugs, can induce respiratory suppression prior to the onset on unconsciousness induced by Embutramide, therefore inducing distress in the animals. For these concerns, Tanax-T61 has been withdrawn from USA market (3). In EU markets, for the purpose of avoiding possible suffering, Tanax-T61 requires to be used only as a euthanasia method in already unconscious pigs (5). The approved leaflet specifically requests: “*In order to avoid possible suffering, before the inoculation of Tanax-T-61, the animal must be subjected to general anesthesia*”. The same specific request is indicated on Tanax-T61 approved leaflet in Israel (6). Other concerns with Tanax-T61 include the potential for pain and irritation during rapid injection (5).

### Mechanical euthanasia

The conditions for euthanasia in a livestock farm differ considerably, for example, from a veterinary clinic when euthanizing a pet, or a scientific laboratory when euthanizing an animal following, or because of, the scientific procedure is executed. Mechanical euthanasia on animals definitely may be displeasing, but from a veterinary point of view, we



Figure 2: Captive bolt.

should consider much more its humane efficacy rather than its aesthetic aspects.

Mechanical euthanasia aims at central nervous system (CNS) destruction, and it practically consists of two main systems: application of a blunt force trauma; or destruction of CNS trough penetration in the brain (3).

The killing of pigs below 5 to 8 kg weight (suckling, weaners) can be done by head percussion with a blunt force trauma (3, 5, 7, 8), which induces extensive and irreversible brain damage, producing almost instantaneous unconsciousness (8). The incomplete development of frontal bones in suckling piglets, allows inducing irreversible damages to the brain, through a high speed force trauma, by swinging them against a solid structure (3, 7, 8). As an alternative, piglets are held by their hind legs, then a heavy but easy to handle object (e.g. club, iron piping) is used to hit on top of head just behind ears (3, 7).

Blunt force trauma percussion requires application of considerable strength, applied with extreme determination and precision; it very often requires a proper training in stockpersons.

Pigs heavier than 8-10 kg (weaners, growers, breeders) are killed by exsanguination, but prior stunning is compulsory in this case. Under Art. 22 of the Regulations, the farm responsible should keep, at the farm level the necessary tools

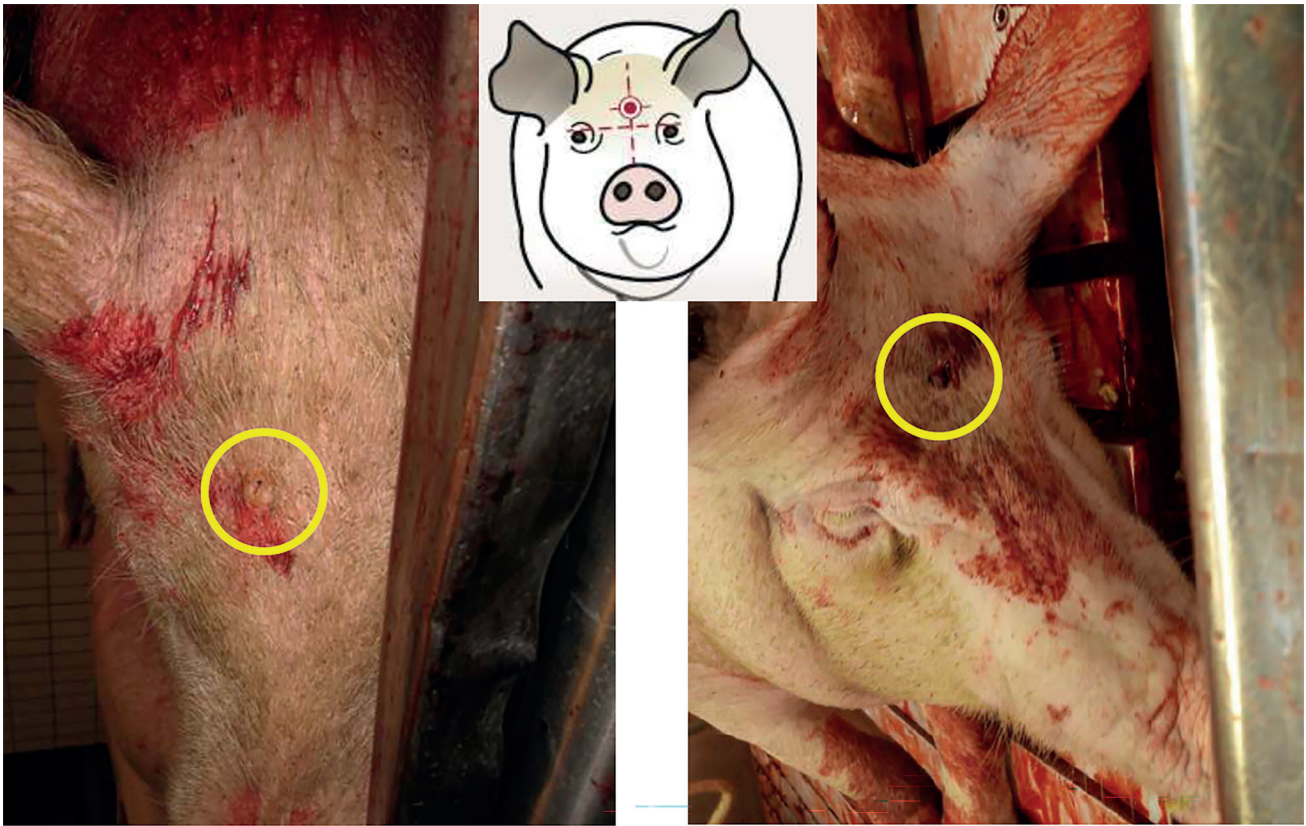
for executing euthanasia in order to prevent the prolonged suffering of animals.

Euthanasia of pigs heavier than 5-8 kg either aims at directly killing the pig (captive bolt), or making it unconscious (electric stunning). Following unconsciousness/stunning, the bleeding must be carried out within 15 seconds so that death may be rapid and painless. As later explained, bleeding is indicated also after captive bolt stunning.

Electric stunners are used in both the two pig slaughterhouses in Israel. Because they require different voltages, amperages and other parameters according to pig (head) size, the equipments are provided with automatic control panels. Therefore, their fine tuning and use may be not be as easy at the farm level, especially if the pigs also need to be transported and positioned in different areas or pens of the farm.

Therefore, as also widely used in other countries, captive bolt represents the easiest tool available for euthanasia of livestock at farm level, both pigs and ruminants. Good handling, calmness, calm without violence, adequate restraining, previous accurate training, are vital for effective stunning to avoid unnecessary pain and fear in the animals (3, 5, 7). Figure 2 represents a captive bolt already in use at Veterinary Services (left) in Israel, and at pig farms in Italy (center, right).

As clearly suggested by the instructions leaflet, the captive bolt may be used in different animal species. Elective point



**Figure 3:** Elective point for stunning in pigs with captive bold equipment.

**Table 2:** Thickness of soft tissues and frontal bone in pigs, forehead position (sows, boars) up to 200 kg; average values and upper limits (from 9; modified)

Gender	Soft tissues, mm		Forehead bone, mm		Total thickness, mm	
	Average	Upper limits	Average	Upper limits	Average	Upper limits
Sows	5.6	7.8	47.1	>58	52.7	>64
Boars	6.4	8.9	34.8	>50	41.5	>56

for stunning in pigs is in the frontal position, on the middle of the forehead on an "X" between the eyes and the upper base of the ears, as illustrated in Figure 3.

In pigs, including breeders, the suggested caliber for pin/rod is 0.22" (5.58 mm) to 0.25" (6.38 mm). The length in standard stunners may be adjusted 12 to 17 cm. Length should be judged in proportion to total thickness of tissues (soft tissues plus frontal bone) in pigs, specially adults, as summarized in Table 2 above.

Thickness of frontal bone, related to weight and sex of pigs, must also be correlated to the propellant charge (cartridge) of the captive bold pistol. Cartridge strength is traditionally indicated in "grains". For use in pigs, the strength should be

2.5 to 3 grains (1 grain = 64.79 mg of gun-powder) of propellant charge. The strength/power of cartridges, is generally indicated with different colors as an easy indicator for farmers/users. In pigs, green/light cartridge may be used in fattening pigs; yellow/average cartridge in sows; blue/heavy cartridge in boars; red cartridges, in general, are used for very heavy animals. Figure 4 illustrates how different strengths of cartridges are very well distinguished by different colors. Higher caliber of pin/rod requires higher cartridge power, correspondence between cartridge powers, pin/rod caliber and target animal for euthanasia, should always be carefully checked. As a practical choice, in many farms a unique strength/color (red/very heavy animals) is often preferred as a precaution.



**Figure 4:** Different cartridges for captive bolt and suggested for use in different categories of pigs.

Two other potential sites for stunning exist in pig, as illustrated in Figure 5

- temporal site: transverse direction, slightly anterior and below the ear, toward the opposite side/ear (“ear to ear”).
- from behind the ear: oblique direction, toward the opposite eye (“ear to eye”)

The temporal site could be taken into account when killing wild boars with a shotgun. Both temporal and behind-ears are generally not practiced in pig farms. The main reasons are: a longer distance from soft tissues (skin) to the brain; a lower alignment “skin to brain”; a higher risk of not damaging the brain sufficiently (9, 10), as summarized in Table 3. Pigs are difficult animals to stun with captive-bolt equipment, because of the small target brain area.

In summary, the frontal shot is recommended at farm level, because of the higher success rate which is due to: less

tissues to penetrate; largest brain/target area; highest success in brain damage.

There are few studies relative to efficacy of mechanical euthanasia at farm level:

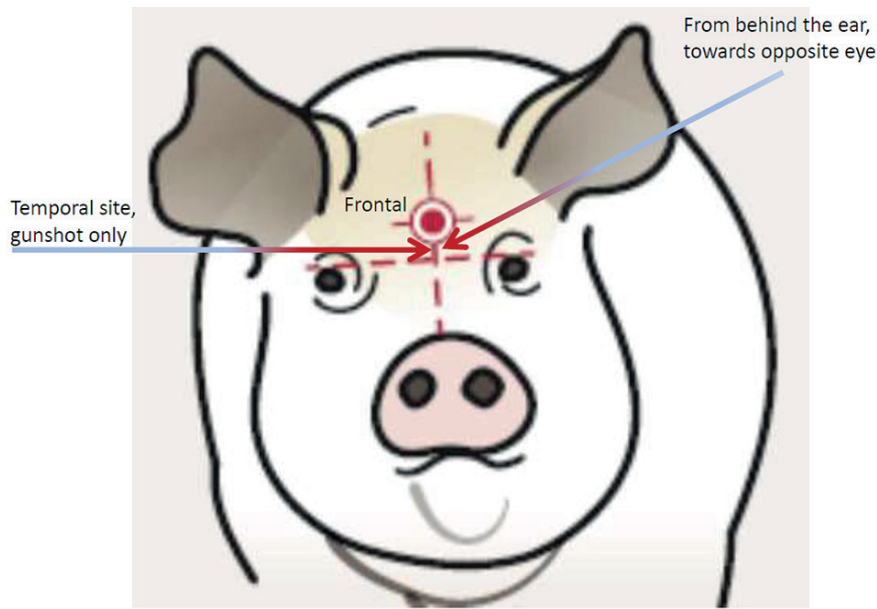
An *in vivo* evaluation of blunt force application on 27 piglets (up to 1.7 kg body weight and less than 1 week of age) in need of euthanasia, showed that blunt force resulted in full effectivity when evaluating behavioral response after its application: no breathing; no vocalization; absence of palpebral, corneal reflexes, and eye blinking; eyeball rotation, etc. At gross pathology evaluation of degree of brain destruction at different areas: frontal, temporal, parietal and occipital. Different areas resulted cumulatively in destruction in all the examined piglets (8).

A captive-bolt mock-stunning research on heavy pigs (9) showed a 91.7% to 96.2% brain damage after stunning, while a previous research publication (10) showed a 97.1% success. Bleeding is therefore strongly suggested after captive-bolt stunning, so that it will also contribute to the death of the animal.

At the end of the killing procedure, animals should be checked for evidence of death. Eye reflexes should be checked to ensure that stunning has rendered the pig unconscious. When the eyelid or cornea is touched there should be no response. An animal that blinks is not properly stunned, and it should be immediately stunned again; however, re-charging captive bolt may take several seconds or even minutes, thus further compromising the welfare of stunned animal (11). A precise training of personnel in charge of euthanizing pigs is therefore necessary. Mock-stunning exercises on site or at slaughterhouse are strongly suggested (3, 7, 9). Rhythmic breathing should have ceased and there should be no indication of a righting reflex. Reflexes may cause a stunned animal's legs to move (8), even in most of the euthanized animals (96%) (8), but piglets should remain recumbent (8),

**Table 3:** Different parameters evaluated when stunning sows and boars in different head positions (from 9, 10, modified)

Stunning position	Category	Distance to brain, mm	Alignment accuracy	Brain damage
Frontal	Sows	52-64	100%	96.2%
	Boars	41-56	100%	91.7%
Temporal	Sows	69-70	97.5%	68.6%
	Boars	73	100%	13.3%
Behind-ear	Sows	90	87.2%	12.5%
	Boars	91	100%	50%



*Schematic picture: courtesy of Publications Office of the European Union, 2018, modified (7).*

**Figure 5:** Frontal, temporal, behind-ear stunning positions; aiming directions (from 7, modified), and according to 9, 10.

the head should hang straight down and be limp. Heart beat does not cease after the captive bolt shot, and it may last several seconds; therefore, bleeding will be a further tool to ensure an efficacious euthanasia.

### Who should carry out euthanasia?

Data from different investigations carried by the authors (unpublished data) in pig farms in North Italy, showed that euthanasia is executed by Veterinarian in 34.2% of examined farms (13/38 farms), and by animal keepers in the other farms (65.8%). Relative to the method used, blunt force trauma is used on piglets up to 5 kg in 96% of farms (24/25 breeding farms); captive bolt is used on growing/fattening pigs in 69.2% of farms (27/39), and on breeders in 68% of farms (17/25). In all the examined farms, jugular bleeding was performed immediately after the blunt method or the captive bolt.

### How much is euthanasia practiced?

Data relative to incidence of euthanasia in pig farms are substantially lacking, with some sparse data relative to breeders which may reach significant euthanasia rates. A 3.27% rate was showed in 11 Canadian farms (12) during 1991-2002; while in 21 Swedish farms euthanasia the rate was 10.5% of all culled sows (13) during a 3 years observation period

(2002-2005). Personal observations (author GBG) from a farm of 1,250 sows between years 2021 to 2023, show an average 2.56% euthanasia rate (minimum 1.84%, maximum 3.52%).

Authors' personal, unpublished, observations from commercial pig farms in Italy are summarized in Tables 4 and 5, below. In 9 observed farms, total euthanized animals were 1,746 out of 101,579 (1.72%); three farms were weaning farms; 6 were fattening farms; pigs populations observed were respectively 42,876 weaners, in 38 productive cycles; and 58,703 fattening pigs, in 25 productive cycles. Percentage of euthanized pigs was 2.62% among weaners and 1.06% in fattening pigs.

In other three different fattening units, belonging to same breeding company, euthanasia prevalence was of 2.93 pigs daily, out 17,450 pigs (starting number); incidence over an observation period of 45 days resulted in 126 euthanized pigs, worth 2.52%, as summarized in Table 7 below.

Undoubtedly, absolute numbers of euthanized animals are important and possibly the same incidences may be assumed for local pig production in Israel: 3,300 to 4,300 estimated pigs in need of euthanasia on yearly basis from weaning (30 days of age) to fattening (180-210 days of age).

Relative to Israel, to the best of authors' knowledge, out of 25 pig farms, only one farm purchased an electric stunner

**Table 4:** Euthanasia rates in weaners and fattening pigs in some farms in North Italy

Growing phase	Number of:			Total euthanized	% of total euthanized
	Farms	Cycles	Animals		
Weaners	3	38	42,876	1,123	2.62
Fatteners	6	25	58,703	623	1.06
Total observations	9	63	101,579	1,746	1.72

**Table 5:** Daily and total euthanized pigs in three fattening units along 45 days growing period

Growing phase	Number of:			Daily euthanized	% euthanized in observed phase
	Farms	Cycles	Animals		
Fatteners	1	1	4,788	0.58	1.82
Fatteners	1	1	3,762	0.91	3.61
Fatteners	1	1	9,033	1.23	2.05
Total observations			17,583	2.93	2.50

(but it is the same farm with its own slaughterhouse; therefore, it is difficult to comprehend if the equipment represents a backup for the plant or the euthanasia tool for the farm). Twenty-four farms did not have any stunner; three farms declared that euthanasia is performed by farm Veterinarian with specific euthanasia drugs. In such a case, these euthanasic treatments should be registered according to Art. 18 of Regulations, and therefore be easily verifiable. No farm had a captive bolt available. As for many other countries, no data are available relative to incidence of euthanized pigs.

## CONCLUSIONS

The euthanasia word derives from the Greek εὖ (*eu*) meaning good/well and θάνατος (*thanatos*) meaning death; it means “good death”, a death that is good for the animal itself (14); and it applies only if the killing is beneficial for the animal itself, and not for others (e.g. killing for purpose of slaughter cannot be defined as “euthanasia”). It is an ethical duty to kill animals, which are in severe pain, and there is no economically viable way or other practical possibility, to alleviate pain. In most of the cases, and especially in animals confined in close farms, animals can be killed respecting proper welfare conditions (15); but in every case, animal keepers should take all the necessary measures to kill animals in severe pain as soon as possible (15).

The Hebrew definition of euthanasia is *המתת חסד* (*hamatat hesed*), which means “compassionate killing”: compassion for

the animals with regards to their suffering. A compassionate decision to carry out euthanasia should indicate whether to end an animal’s life, and how to do it.

Penetrative captive bolt devices are clearly enlisted, both in the Annex I of EU Regulation (15) and at Art. 22 of Israeli Regulations, among the acceptable methods for the killing of animals. Captive bolt devices are cheap, easy to use, highly efficient, especially when properly combined with bleeding after the shot. Captive bolt pistols may involve human risk and are potentially lethal and therefore require skill and experience (16). Training is therefore essential to ensure correctness and effectiveness of euthanasia, and according to both EU (15) and Israeli Regulations, training is compulsory for livestock keepers. Training courses, approved by authorities, should be available for personnel involved in farming and, therefore, in euthanizing animals, when necessary (15). Authorities should approve contents and, if necessary, final examination for these courses, even if teaching itself may be delegated to separate bodies or entities of proved expertise and competence (15). Personal observations of the authors in pig farms in north Italy showed that in 60 out of 65 farms at least one animal keeper received a formal training relative to euthanasia in pigs (92.3%). At best of our knowledge, such a kind of training has never been organized in Israel.

When used by trained, skilled person, the captive bolt technique is definitely more efficacious and precise than the blunt method causing less stress, fear and anxiety (because



of very short immobilization); it induces a quick, painless, and therefore more humane unconsciousness and death with respect to other methods (16).

Unfounded reasonings relating to security should be put apart and every pig farm should have available a captive bolt stunner, appoint at least two persons for its use, after specific training course under art. 22 of Regulations, as responsible for euthanasia in irrecoverable animals, in order to spare them any unnecessary suffering. The farm Veterinarian, together with the farmer, should agree on written procedures relative to for example clinical cases, diseases, injuries, malformations, etc., which would require the euthanasia of the pig with the purpose of sparing unnecessary suffering.

### Animal Welfare statement

No animal was sacrificed or euthanized for the purpose of realizing this paper:

- Figure 2 results from official audits carried by Veterinary Services in Israel; animals were then euthanized.
- Figure 4 results from routine back-up stunning executed at a slaughter plant.

### REFERENCES

1. Ministry of Agriculture, The Veterinary Services, "Procedure: Treatment of a down animal in the farm"; update 2, 2018, [https://www.gov.il/BlobFolder/policy/moag-pro-034/he/procedure\\_tipul\\_behema\\_rovetzet.pdf](https://www.gov.il/BlobFolder/policy/moag-pro-034/he/procedure_tipul_behema_rovetzet.pdf)
2. Ministry of Health, The Israeli Drug Registry; <https://israeldrugs.health.gov.il>
3. American Veterinary Medical Association (AVMA) "Guidelines for the euthanasia of animals" 2020 Ed., 1931 N. Meacham Road Schaumburg, 60173 IL (USA); ISBN 978-1-882691-09-8
4. Rumney, H.: Dispensing barbiturates to swine producers. *Can. Vet. J.* 46:106, 2005.
5. European Food Safety Agency (EFSA), "Scientific Opinion on the welfare of pigs during killing for purposes other than slaughter", *EFSA Journal*, 18(7):6195, 2020, <https://doi.org/10.2903/j.efsa.2020.6195>
6. T-61 Veterinary; approved leaflet by Ministry of Health; 2016, <https://israeldrugs.health.gov.il/#/medDetails/083%2001%2092344%2001>
7. How to stun pigs/kill pigs on-farm, 2018, Luxembourg, Publications Office of the European Union, 2018. [https://food.ec.europa.eu/system/files/2021-08/aw\\_prac\\_slaughter\\_factsheet-2018\\_farm\\_pigs\\_en.pdf](https://food.ec.europa.eu/system/files/2021-08/aw_prac_slaughter_factsheet-2018_farm_pigs_en.pdf)
8. Dalla Costa, F., Gibson, T., Oliveira, S.E., Gregory, N., Caldarella, A., Faucitano, L., Ludtke, C., Buss, L. and Dalla Costa, O.: Evaluation of physical euthanasia for neonatal piglets on-farm, *Journal of Animal Science*. 98(7):1-11, 2020. <https://doi.org/10.1093/jas/skaa204>
9. Anderson, K. N., Allen, K. J., Baysinger, A., Benjamin, M., Berger, J., Claus, J. R., Greco, B. J., Massie, E. A., O'Brien, B., Ramirez, A., Rendahl, A. K., Reyes, A. A., Zhitnitskiy, P. E. and Vogel, K. D.: Relationship of tissue dimensions and three captive bolt placements on cadaver heads from mature swine (*Sus scrofa domesticus*) > 200 kg body weight. *J. Anim. Sci.* 99(12), 2021. <https://doi.org/10.1093/jas/skab327>
10. Woods, J., Hill, J., Schwartz, K., Grandin, T., Brooks, R., O'Connor, A. and Johnson, A.: On-farm validation of captive bolt technology as a single stage euthanasia method –NPB #09-196. Research Report, Iowa State University & National Pork Board, Des Moines, IA, USA, 2012, <https://porkcheckoff.org/wp-content/uploads/2021/02/09-196-MILLMAN-ISU-revised.pdf>
11. Atkinson S., Velarde A. and Algers B.: Assessment of stun quality at commercial slaughter in cattle shot with captive bolt. *Animal Welfare*, 22: 473-481, 2013.
12. Anil, S.S., Anil, L. and Deen, J.: Evaluation of patterns of removal and associations among culling because of lameness and sow productivity traits in swine breeding herds. *J. Am. Vet. Med. Ass.* 226(6): 956-961, 2005.
13. Engblom, L., Lundeheim, N., Dalin, A.M. and Andersson, K.: Sow removal in Swedish commercial herds. *Livestock Science*. 106(1):76-86, 2007. <https://doi.org/10.1016/j.livsci.2006.07.002>
14. Broom, D. M.: Animal Welfare in the European Union. Research paper requested by the European Parliament's Committee on Petitions, 2017. [https://www.europarl.europa.eu/RegData/etudes/STUD/2017/583114/IPOL\\_STU\(2017\)583114\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2017/583114/IPOL_STU(2017)583114_EN.pdf)
15. COUNCIL REGULATION (EC) No 1099/2009 "on the protection of animals at the time of killing", 2009, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R1099>
16. Iowa State University; College of Veterinary Medicine; Veterinary Diagnostic and Production Animal Medicine, "Gunshot or Penetrating Captive Bolt"; accessed 07/2023 <https://vetmed.iastate.edu/vdpam/about/production-animal-medicine/dairy/dairy-extension/humane-euthanasia/humane-euthanasia/gunshot-or-penetrating-captive-bolt>