Hematological parameters of pigs in different housing systems in Slovenia

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Abstract

Objectives: Establish blood reference values and evaluate the influence of age on the hematological profile of indigenous Slovenian Krškopolje pigs and compare these values with conventionally farmed pigs.

Materials and methods: Blood samples were taken from 57 grower and 36 finisher Krškopolje pigs from 2 organic farms and 183 grower and 47 finisher pigs from 6 conventional farms in Slovenia. Samples were analyzed using an automatic hematology analyzer to measure white blood cell count, red blood cell count (RBC), hematocrit (Hct), hemoglobin concentration (Hb), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and platelet count (PLT).

Results: The hematological parameter reference values of the Krškopolje pig breed corresponded with reference ranges in the literature. Pig age had a significant effect on hematologic parameters. Organic grower pigs had significantly higher RBC and MCHC values and lower Hct, MCV, and MCH values than conventional pigs. Organic finisher pigs had significantly higher PLT values and lower Hb, Hct, MCV, and MCH values than conventional pigs. All reported differences in hematologic values between Krškopolje and conventional pigs are not expected to affect clinical outcomes.

Implications: These hematologic reference values can be used as a diagnostic tool for assessing the health status of Krškopolje pigs, but pig age must be accounted for. Reference values from the literature are suitable for assessing the health status of both conventionally and organically reared pigs.

Keywords: swine, hematology, reference values, indigenous pig breed, conventional breed

Received: May 13, 2024
Accepted: September 16, 2024
Published online: January 23, 2025

Resumen - Parámetros hematológicos de cerdos en diferentes sistemas de alojamiento en Eslovenia

Objetivos: Establecer valores de referencia en sangre y evaluar la influencia de la edad en el perfil hematológico de cerdos Krškopolje autóctonos eslovenos y comparar estos valores con cerdos de granja convencional.

Materiales y métodos: Se tomaron muestras de sangre de 57 cerdos Krškopolje de engorde y 36 cerdos de engorde de 2 granjas ecológicas, y de 183 cerdos de engorde, y 47 cerdos de engorde de 6 granjas convencionales de Eslovenia. Las muestras se analizaron utilizando un analizador automático de hematología para medir el recuento de glóbulos blancos, el recuento de glóbulos rojos (RBC), el hematocrito (Hct), la concentración de hemoglobina (Hb), el volumen corpuscular medio (MCV), la hemoglobina corpuscular media (MCH), la concentración media de hemoglobina corpuscular (MCHC), y el recuento de plaquetas (PLT).

Resultados: Los valores de referencia de los parámetros hematológicos de la raza porcina Krškopolje correspondieron con los rangos de referencia de la literatura. La edad del cerdo tuvo un efecto significativo sobre los parámetros hematológicos. Los cerdos de engorde orgánicos tuvieron valores significativamente más altos de RBC y MCHC, y valores más bajos de Hct, MCV, y MCH que los cerdos convencionales. Los cerdos de engorde orgánicos tuvieron valores de PLT significativamente más altos y valores más bajos de Hb, Hct, MCV, y MCH que los cerdos convencionales. No se espera que todas las diferencias detectadas en los valores hematológicos entre Krškopolje y los cerdos convencionales afecten los resultados clínicos.

Implicaciones: Estos valores de referencia hematológicos pueden utilizarse como herramienta diagnóstica para evaluar el estado de salud de los cerdos de Krškopolje, pero hay que tener en cuenta la edad de los cerdos. Los valores de referencia de la bibliografía son adecuados para evaluar el estado sanitario de los cerdos criados tanto de forma convencional como ecológica.

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Golinar Oven I, Plut J, Hajdinjak M, Šteferl T, Nadlučnik E, Štukelj M. Hematological parameters of pigs in different housing systems in Slovenia. *J Swine Health Prod*. Published online January 23, 2025. **https://doi.org/10.54846/jshap/1410**

Résumé - Paramètres hématologiques de porcs dans différents systèmes d'hébergement en Slovénie

Objectifs: Établir les valeurs de référence sanguines et évaluer l'influence de l'âge sur le profil hématologique de porcs indigènes slovènes Krškopolje et comparer ces valeurs avec celles de porcs élevés en fermes conventionnelles.

Matériels et méthodes: Des échantillons de sang ont été obtenus de 57 porcs Krškopolje en croissance et de 36 porcs Krškopolje en finition de 2 fermes biologiques et de 183 porcs en croissance et 47 porcs en finition de 6 fermes conventionnelles en Slovénie. Les échantillons ont été analysés au moyen d'un appareil hématologique automatique afin de mesurer le comptage leucocytaire, le comptage de globules rouges (RBC), l'hématocrite (Hct), la concentration en hémoglobine (Hb), le volume corpusculaire moyen (MCV), l'hémoglobine corpusculaire moyenne (MCH), la concentration moyenne d'hémoglobine corpusculaire (MCHC) et le comptage de plaquettes (PLT).

Résultats: Les valeurs de référence des paramètres hématologiques des porcs de race Krškopolje correspondaient avec les plages de référence dans la littérature. L'âge des porcs avait un effet significatif sur les paramètres hématologiques. Les porcs en croissance biologiques avaient des valeurs de RBC et de MCHC significativement plus élevées et des valeurs de Hct, MCV, et MCH plus basses que les porcs conventionnels. Les porcs en finition biologiques avaient des valeurs de PLT significativement plus élevées et des valeurs de Hb, Hct, MCV, et MCH plus basses que les porcs conventionnels. On ne s'attend pas à ce que toutes les différences hématologiques rapportées entre les porcs Krškopolje et les porcs conventionnels affectent des résultats cliniques.

Implication: Ces valeurs de référence hématologiques peuvent être utilisées comme outil diagnostique pour évaluer l'état de santé de porcs Krškopolje, mais l'âge des porcs doit être pris en compte. Les valeurs de référence obtenues de la littérature sont acceptables pour évaluer l'état de santé de porcs élevés de manière conventionnelle ou biologique.

Hematologic examination can be an important diagnostic tool for assessing the health status of pigs but is rarely performed. Blood sampling in pigs is difficult and causes stress, which is one of the main sources of hematologic variation.[1] Many reference intervals for pigs have been published, but the ranges for most hematologic parameters are quite wide. A variety of environmental and physiological factors must be considered when interpreting the results of hematology analyses, including age, sex, diet, stage of gestation, housing system, management practices, time of year, blood collection technique, sample preparation, and the type of analysis equipment used.[1-3]

The evaluation of hematological parameters in pigs can be valuable in the treatment or prognosis of many diseases,[4] can contribute to the early detection of pathological conditions, and reflect metabolic disorders due to nutrient deficiencies.[5-7] Diet can influence the hematologic values of animals and can be used as a suitable measure of long-term nutritional status.[8] In a trial conducted by Lee et al,[9] increasing the concentration of tannic acid (125 to 1000 mg/kg) in the weaning diet resulted in a linear reduction in red blood cell (RBC) count, hemoglobin (Hb), and hematocrit (Hct) on days 21 and 28 of treatment.

In recent years, a new generation of consumers has become enthusiastic about organic and free-range farming as an alternative to indoor farming, as they are perceived to be associated with health, sustainability, food safety, and animal welfare. The differences between organic and conventional pig farming lie in the breed, stocking density, animal husbandry, feeding, and treatment of diseases. Physical activity, a factor emphasized in organic and free-range farming, and different management methods, such as housing type, can influence blood values.[10] Slovenian pig farms are small and fragmented, agricultural land is limited, and natural conditions are not favorable for larger scale pig farms. Pig farming makes up a small part of Slovenian agriculture, as the self-sufficiency rate for pork is only 20% to 25%. Slovenia has 253,770 pigs kept on 12,843 farms. Only 22 of these farms are considered large with more than 1000 pigs and 11,631 farms are small with 20 or less pigs.[11]

The Krškopolje pig is the only preserved indigenous pig breed in Slovenia. The breed was threatened with extinction, but the promotion and support of organic farming has increased interest in the breed. The breed is adapted to poor rearing conditions, is robust, and is feed efficient making it suitable for outdoor production.[12] The average daily gain of the Krškopolje pig during the growth phase is lower than that of modern breeds.[13,14] Krškopolje pigs are reared in various housing systems including conventional indoor housing, outdoor housing with shelter, and indoor housing only in very cold winters.[12] Recently, there have been more organic farms in Slovenia using the Krškopolje pig breed, as its meat is highly appreciated by consumers.

The aims of this study were to establish hematological reference values for grower and finisher Krškopolje pigs to be used for clinical interpretation of laboratory data and evaluate the influence of age on hematological parameters. Additionally, this study compares hematological values of Krškopolje pigs with those of conventional pig breeds on Slovenian farms to determine whether any differences are clinically relevant.

Animal care and use

All procedures in this study were carried out in accordance with Directive 2010/63/EU of the European Parliament and the Council on the Protection of Animals used for Scientific Purposes and the Slovenian Animal Protection Law (Official Gazette of the Republic of Slovenia No. 38/2013 and 21/2018) and accepted by the National Ethics Committee. This study was carried out as a part of the ERA-Net CORE Organic Cofound project - Robust animals in sustainable mixed free-range systems project (ROAM-FREE) and was ethically approved by the Ministry of Agriculture, Forestry, and Food (U34401-6/2022/11).

Materials and methods

Farms and animals

The study was conducted in Slovenia between 2022 and 2023 on 2 organic farms (one with 180 animals and the other with 40 animals) and 6 conventional farms (2 large 1-site farms, with 1000 and 1850 breeding sows, respectively, one 2-site farm with 600 breeding sows, and 3 small 1-site farms each with 100 breeding sows). The animals from both organic farms originated from the same

Slovenian organic pig farm and were the indigenous Slovenian Krškopolje pig breed. The sows on the conventional farms were maternal hybrids (H12) with the dam from the Slovenian Landrace - Line 11 and the sire from the Slovenian Large White.

Organic housing systems are divided into indoor, outdoor, and mixed housing. The types of barns range from heated buildings with artificial ventilation to open-front barns. Organic standards require that animals are kept with outdoor access. In indoor housing, the pigs have access to an outdoor run. According to national rules and based on national interpretation of the EU regulations for organic farming (Council Directives 2007/834/EC and 2008/889/EC), outdoor runs vary from concrete and slatted floors to deep litter and from open to fully covered by a roof. In outdoor housing, the animals are kept outside all year round with shelter. In mixed housing systems, various combinations of indoor and outdoor housing are used. For finishing pigs weighing up to 50 kg, 0.8 m^2/head are required for the indoor area and 0.6 m^2/head for the outdoor area (excluding pasture). The total stocking density must not exceed 170 kg of nitrogen per year and hectare of agricultural area (the maximum number of finishing pigs per hectare is 14). The use of chemically synthesized allopathic veterinary medicinal products or antibiotics for preventive treatment is prohibited. The feed used in organic farming must come from organic production, at least 20% of which must come from the farm itself.

In our study, pigs on the larger organic farm were reared outdoors on a large grass pasture (9000 m^2) with 2 straw-bedded dugouts. A nipple drinker and feeder were provided. In winter, these pigs were housed indoors in a large pen bedded with straw. Pigs on the smaller organic farm were reared outdoors on a large grass pasture (12,600 m^2) and had one covered wooden shelter. The shelter was bedded with straw and had one water trough and one feed trough inside.

The conventional farms in our study were indoor farms, two small farms had outdoor runs for growers and finishers. All farms had a ventilation system. However, one small farm used natural ventilation most of the time because the ventilation system was not working properly. The floors in the conventional farms were partially slatted, with two small farms also having solid floors.

All farms had nipple and bowl drinkers, usually two in each pen. Two large farms had floor feeding, the others had hoppers and troughs. The size of the pen groups varied from 18 to 25 pigs/pen on all farms, but a minimum unobstructed floor area of 0.40 m^2 was provided for a growing pig (30-50 kg pigs).

On both the organic and conventional farms, the male piglets were surgically castrated in the first week of life. Piglets on organic farms received analgesia at castration.

Previous treatment

Pigs from conventional farms were vaccinated against *Mycoplasma hyopneumoniae*, porcine circovirus 2 (PCV2), and sows vaccinated against *Echerichia coli* and atrophic rhinitis. Pigs from organic farms were vaccinated against *Erysipelothrix rhusiopathiae.* Treatments against endoparasites and ectoparasites were carried out on all growing pigs from organic and conventional farms when they reached 25 to 30 kg. Fecal samples were collected and pooled from each farm and examined for internal parasites using flotation and sedimentation techniques; clinically insignificant levels of *Balantidium coli* were found on all farms. All farms were certified to be free of classical swine fever, African swine fever, pseudorabies, porcine reproductive and respiratory syndrome, *Clostridium perfringens C*, *Brachyspira hyodysenteriae,* and *Salmonella*. All piglets from organic and conventional farms were given 200 mg/mL iron in a dose of 1 mL (trivalent iron in the form of an iron hydroxide complex with dextran) intramuscularly in the first three days of life. Clinical examination of the herd was carried out during a site visit and animals were observed to be clinically healthy at the time of blood sampling.

Nutrition

On the conventional farms, breeding animals were fed twice daily and grower-finisher pigs were fed *ad libitum,* each with commercially produced feed. The diets contained corn, wheat, barley, and soybeans and were supplemented with complementary feed and mineral-vitamin mixtures according to NRC category recommendations.[15] Pigs on the organic farms were fed an organic diet consisting of 60% barley, 30% wheat, and 10% sunflower meal. Pigs on the small organic farm were fed twice daily, 35 kg of feed in the morning and 15 kg of feed in the afternoon. Pigs on the large organic farm were fed *ad libitum*.

No other additives (eg, therapeutics or nostrums) were added to the feed on any of the farms.

Blood sample collection

Blood samples were collected from 57 grower and 36 finisher pigs from organic farms and 183 grower and 47 finisher pigs from conventional farms. Grower pigs were 7 to 14 weeks of age. The animals were randomly selected and individual blood samples for hematological analysis were taken from the anterior vena cava in tubes containing K_3EDTA anticoagulant (Vacuette, Greiner Bio-One). The tubes were gently shaken by hand for 30 seconds to ensure mixing of blood and anticoagulant. The samples were transported in a box at 4°C and the analyses were performed on the day of sampling.

Hematological analyses

Individual blood samples were analyzed using an automated hematology analyzer, the scil Vet abc Plus (Horiba). The following hematologic variables were measured: white blood cell count (WBC), red blood cell count (RBC), hematocrit (Hct), hemoglobin concentration (Hb), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and platelet count (PLT). The laboratory where the analyses were performed participated in the Randox International Quality Assessment Scheme Hematology Program.

Statistical analyses

Statistical analyses were performed using the R software package (version 4.3.2).[16] Bartlett's test was used to test for homoscedasticity, ie, whether multiple samples came from populations with equal variances. If the Bartlett's test for homoscedasticity on samples from different types of husbandry (organic farms versus conventional farms) gave $P \geq .05$, the null hypothesis that all population variances were equal was not rejected against the alternative that at least two were different. Therefore, Student's *t*-test and analysis of variance, which assume that the population variances are equal, were used to determine whether the type of husbandry affected the hematological parameters of the pigs. If Bartlett's test for homoscedasticity on samples from different types of husbandry practices gave $P < .05$, the null hypothesis that all population variances were equal was rejected against the alternative that at least two were different. Therefore, the variances were not considered equal, and the Welch's *t*-test (or unequal variances *t*-test) was used to test whether the different types of husbandry practices gave statistically different means for hematological parameters. Welch's *t*-test is a two-sample location test, an adaptation of the Student's *t*-test, which is more reliable when samples have unequal variances and possibly unequal sample sizes. The level of significance was set at $P < .05$.

Reference intervals were estimated using the refineR function in R, which implements the recently published, state-of-the-art indirect method.[17] It takes routine measurements of diagnostic tests as input and uses sophisticated statistical methods to derive a model describing the distribution of the non-pathological samples. The distribution is then used to derive reference intervals.

Results

The hematological values, the reference intervals of the Krškopolje pigs during the growing and finishing phase, and reference values from the literature are shown in Table 1. The hematological values for both age categories of Krškopolje pigs are within the reference values from the literature. Age significantly influenced values of WBC, Hb, Hct, MCV, MCH, and PLT.

Table 2 shows the hematological values of grower pigs from organic and conventional farms. The RBC and MCHC were significantly higher, and the Hct, MCV, and MCH were lower in grower pigs from organic farms than in pigs of the same age from conventional farms. Table 3 shows the hematological values of finisher pigs from organic and conventional farms. The PLT were significantly higher and Hb, Hct, MCV, and MCH were lower in finisher pigs from organic farms than those from conventional farms.

Discussion

Hematologic reference values for different age groups of pigs have already been reported,[2,3,5,18,19] especially for conventional pig breeds kept on conventional farms. In this study, hematological reference values for grower and finisher Krškopolje pigs were determined for the first time. When comparing hematological parameter values of grower and finisher Krškopolje pigs with the reference values from the literature,[1,20] no clinically relevant differences were found. Hematological reference values presented for the Krškopolje pig provide a basis for the interpretation of hematologic results

Table 1: Hematological values of grower (7-14 wk old) and finisher Krškopolje pigs from two organic farms and reference values from the existing literature

Parameter	Age	Mean (median)	Range*	*P*	Reference values (mean)
WBC, 10^9/L	Growers	24.01 (23.85)	16.22-30.35	< .001	13.70-34.12 (22.44)† 18.9-33.8 (26.9)‡
	Finishers	18.86 (17.95)	16.68-18.85		14.10-32.10 (20.97) †
RBC, 10^{12}/L	Growers	6.74 (6.72)	6.57-6.91	.07	5.40-7.28 (6.43)† 6.4-8.0 (7.1)‡
	Finishers	7.02 (7.04)	6.86-7.45		5.74-8.63 (6.92)†
Hb, g/dL	Growers	10.87 (10.90)	9.79-11.15	< .001	9.2-12.5 (10.9)† 11.5-13.3 (12)‡
	Finishers	11.87 (11.90)	11.59-12.17		11.1-14.4 (12.6)†
Hct, %	Growers	35.02 (35.20)	32.44-38.10	< .001	28.0-41.7 (35.3)† 38-44 (40)‡
	Finishers	38.14 (38.50)	36.73-39.81		34.1-48.7 (39.9)†
MCV, μm^3	Growers	52.02 (52.00)	50.25-55.39	.002	47.7-63.0 (54.9)† 53-61 (57)‡
	Finishers	54.61 (56.00)	56.93-58.93		50.0-64.8 (57.8)†
MCH, pg/cell	Growers	16.15 (16.20)	15.60-16.93	.001	14.0-18.5 (17.1)†
	Finishers	17.00 (17.35)	17.69-18.29		16.1-20.9 (18.4)†
MCHC, g/dL	Growers	31.06 (31.0)	30.37-31.25	.58	28.8-33.5 (31.1)† 28-31 (30)‡
	Finishers	31.12 (31.20)	30.94-31.41		29.2-33.7 (31.7)†
PLT, 10^9/L	Growers	427.12 (427.00)	362.10-508.41	.01	273-730 (483)†
	Finishers	369.06 (358.00)	330.92-350.42		134-584 (336)†

* 2.5th to 97.5th inter-percentile range.

† Reference ranges taken from Ježek et al.[3]

‡ Reference ranges taken from Thorn.[1] Both sexes were 3.5-4 months old.

WBC = white blood cell count; RBC = red blood cell count; Hb = hemoglobin concentration; Hct = hematocrit; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; PLT = platelet count.

Table 2: Hematological values of grower pigs on organic and conventional farms

Parameter	OF, Mean (SD)	CF, Mean (SD)	*P* Bartlett	Student *t*	Welch *t*
WBC, 10^9/L	24.01 (6.85)	22.15 (6.12)	.29	.56	NA
RBC, 10^{12}/L	6.74 (0.67)	6.24 (0.87)	.02	NA	< .001
Hb, g/dL	10.87 (1.09)	11.25 (1.37)	.04	NA	.94
Hct, %	35.02 (3.57)	38.84 (5.01)	.003	NA	.002
MCV, μm^3	52.02 (3.33)	60.30 (4.42)	.01	NA	< .001
MCH, pg/cell	16.15 (1.05)	17.43 (1.22)	.16	< .001	NA
MCHC, g/dL	31.06 (0.54)	29.06 (1.44)	< .001	NA	< .001
PLT, 10^9/L	427.12 (110.75)	365.73 (147.00)	.01	NA	.17

OF = organic farms; CF = conventional farms; NA = not analyzed; WBC = white blood cell count; RBC = red blood cell count; Hb = hemoglobin concentration; Hct = hematocrit; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; PLT = platelet count.

Table 3: Hematological values of finisher pigs on organic and conventional farms

Parameter	OF, Mean (SD)	CF, Mean (SD)	*P* Bartlett	Student *t*	Welch *t*
WBC, 10^9/L	18.86 (3.18)	20.11 (4.53)	.03	NA	.14
RBC, 10^{12}/L	7.02 (0.75)	6.85 (0.79)	.72	.33	NA
Hb, g/dL	11.87 (1.00)	12.76 (1.22)	.22	< .001	NA
Hct, %	38.14 (3.21)	40.62 (4.60)	.02	NA	.004
MCV, μm^3	54.61 (4.16)	59.67 (2.87)	.01	NA	< .00
MCH, pg/cell	17.00 (1.32)	18.69 (1.08)	.20	< .001	NA
MCHC, g/dL	31.12 (0.53)	31.31 (1.03)	< .001	NA	.26
PLT, 10^9/L	369.06 (101.29)	264.74 (101.66)	.98	< .001	NA

OF = organic farms; CF = conventional farms; NA = not analyzed; WBC = white blood cell count; RBC = red blood cell count; Hb = hemoglobin concentration; Hct = hematocrit; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; PLT = platelet count.

from individual animals or from herds with clinical signs or conditions that may be subclinical.

The results of our study show that the hematological parameters of Krškopolje pigs are age-associated; they differ significantly between two age groups (growers and finishers). This is consistent with previous results.[3,21] As this is a field study, we cannot say with certainty that the differences in hematological results are due to age rather than variables (eg, feed or facility types) associated with the age group.

Reference values were calculated separately for Krškopolje grower and finisher pigs, as the differing values of WBC, Hb, Hct, MCV, and PLT seem to be clinically relevant between these age groups. The mean hematological parameter values for grower and finisher pigs in this study differ from published reference values for sows, which can be attributed to physiological changes during the maturation process.[1,3,22]

In our study, we found significant differences in some hematological parameters between pigs raised on organic farms or conventional farms. Higher RBC values in pigs on organic farms could result from greater muscle activity, as pigs on organic farms had the ability to move more.[20] Pig breeds that grow faster may have a lower concentration of RBCs in their bloodstream. Due to rapid muscle development, blood volume increases while RBC production may not keep pace.[23] Grower and finisher pig Hct and finisher pig Hb were lower in Krškopolje pigs than in pigs from conventional farms. When finisher pigs reach the desired market weight, their metabolic requirements decrease, and blood Hb and Hct levels often decrease as well.[24] In our study, the finishers had not yet reached market weight, so Hb and Hct levels were still higher in the finishers than in the growers on both organic and conventional farms.

Diet can also contribute to differences in the hematological profile. The animals on the organic farm received organically produced feed (barley, wheat, and sunflower seeds), with the grower and finisher pigs receiving the same diet. Free-range farming with grazing systems facilitates a natural lifestyle but carries a higher risk of nutrient leaching.[25] For example, lower Hb and Hct values in organic farms could be due to a lack of protein in the feed; lower Hb values also occur in the case of amino acid deficiencies and chronic parasitic diseases.[20] Pigs from organic farms had significantly higher PLT values. The number of PLT fluctuate due to physiological adaptations to physical exertion (increasing considerably after hard work), seasons (increasing in colder temperatures), and altitudes (increasing at higher altitudes).[20] The animals on the organic farms were more physically active, as they had larger space allowance. Both organic farms were located at an altitude between 556 and 700 m above sea level. The conventional farms were located at an altitude of 163 to 380 m above sea level, which could have contributed to their lower PLT values. Significant differences between pigs of the same age raised on organic or conventional farms may also be due to differences in the breed of the animals.

Despite the identified changes in some hematological parameters between Krškopolje pigs raised on organic farms and pigs raised on conventional farms, all hematological values were within published reference values.[3,20] Therefore, we do not expect that the differences in hematological values observed in this study will be reflected in the health status of the pigs.

Implications

Under the conditions of this study:

- Reference values help interpretation of hematological results for pig health.
- Age-related changes in hematological parameters occurred.
- Published reference values are suitable for organic and conventional farmed pigs.

Acknowledgments

We wish to express our gratitude to farm personnel, farm owners, the local veterinarians, and veterinary students for their help in conducting this study.

This study was cofunded by the European Union under the ERA-NET CORE Organic project robust animals in sustainable mixed free-range systems (ROAM-FREE) and the Slovenian Research and Innovation Agency (ARIS) under the research program P4-0092 – Animal health, environment and food safety.

Conflict of interest

None reported.

Disclaimer

References

1. Thorn CE. Hematology of the pig. In: Weiss DJ, Wardrop KJ, Schalm OW, eds. *Schalm's Veterinary Hematology.* 6th ed. Wiley Blackwell; 2010:843-851.

2. Friendship RM, Lumsden JH, McMillan I, Wilson MR. Hematology and biochemistry reference values for Ontario swine. *Can J Comp Med.* 1984;48:390-393.

3. Ježek J, Starič J, Nemec M, Plut J, Golinar Oven I, Klinkon M, Štukelj M. The influence of age, farm, and physiological status on pig hematological profiles. *J Swine Health Prod.* 2018;26(2):72-78. **https://doi.org/10.54846/jshap/1049**

4. Eze JI, Onunkwo JI, Shoyinka SVO, Chah FK, Ngene AA, Okolinta N, Nwanta JA, Onyenwe IW. Haematological profiles of pigs raised under intensive management system in south-eastern Nigeria. *Nig Vet J.* 2010;31:115-123. **https://doi.org/10.4314/nvj.v31i2.68958**

5. Perri AM, O'Sullivan TL, Harding JCS, Wood RD, Friendship RM. Hematology and biochemistry reference intervals for Ontario commercial nursing pigs close to the time of weaning. *Can Vet J.* 2017;58:371-376.

6. Ventrella D, Dondi F, Barone F, Serafini F, Elmi A, Giunti M, Romagnoli N, Forni M, Bacci ML. The biomedical piglet: Establishing reference intervals for haematology and clinical chemistry parameters of two age groups with and without iron supplementation. *BMC Vet Res.* 2017;13:23. **https://doi.org/10.1186/s12917-017-0946-2**

7. Sanchez NCB, Carroll JA, Corley JR, Broadway PR, Callaway TR. Changes in the hematological variables in pigs supplemented with yeast cell wall in response to a *Salmonella* challenge in weaned pigs. *Front Vet Sci.* 2019;6:1-13. **https://doi.org/10.3389/fvets.2019.00246**

8. Etim NN, Offiong EEA, Williams ME, Asuquo LE. Influence of nutrition on blood parameters of pigs. *Am J Biol Life Sci.* 2014;2(2):46-52.

9. Lee SH, Shinde PL, Choi JY, Kwon IK, Lee JK, Pak SI, Cho WT, Chae BJ. Effect of tannic acid supplementation on growth performance, blood hematology, iron status and faecal microflora in weanling pigs. *Livest Sci.* 2010;131:281-286. **https://doi.org/10.1016/j.livsci.2010.04.013**

10. Martins JM, Silva D, Albuquerque A, Neves J, Charneca R, Freitas A. Physical activity effects on blood parameters, growth, carcass, and meat and fat composition of Portuguese Alentejano pigs. *Animals (Basel).* 2021;11:156. **https://doi.org/10.3390/ani11010156**

11. Statistical Office of the Republic of Slovenia. Livestock number, 1. 12. 2021. Published February 11, 2022. Accessed March 1, 2024. **https://www.stat.si/StatWeb/en/news/Index/10139**

12. Batorek Lukač N, Tomažin U, Škrlep M, Kastelic A, Poklukar K, Čandek-Potokar M. Krškopoljski prašič [Krškopolje Pig]. In: Čandek-Potokar M, Nieto Linan R, eds. *European Local Pig Breeds - Diversity and Performance. A study of project TREASURE.* IntechOpen; 2019. Accessed March 15, 2024. **https://doi.org/10.5772/intechopen.83767**

13. Tomažin U, Mežan A, Kastelic A, Batorek-Lukač N, Škrlep M, Čandek-Potokar M. Rastnost pujskov krškopoljske pasme do konca vzreje [The growth of piglets of the Krškopolje breed until the end of breeding]. In: *Proceedings of the 24th International Scientific Symposium on Nutrition of Farm Animals.* Kmetijsko Gozdarska Zbornica Slovenije, Kmetijsko Gozdarski Zavod; 2015:8.

14. Mežan A, Kastelic A, Tomažin U, Čandek-Potokar M. Spremljanje rasti sesnih pujskov pasme krškopoljski prašič [Monitoring the growth of suckling piglets of the Krškopolje pig breed]. *Kmetovalec.* 2015;83:13-14.

15. National Research Council. *Nutrient Requirements of Swine.* 11th ed. National Academies Press; 2012.

16. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing; 2013. Accessed January 12, 2024. **https://www.R-project.org**

17. Ammer T, Schützenmeister A, Prokosch H-U, Rauh M, Rank CM Zierk J. refineR: A novel algorithm for reference interval estimation from real-world data. *Sci Rep.* 2021;11:16023. **https://doi.org/10.1038/s41598-021-95301-2**

18. Klem TB, Bleken E, Morberg H, Thoresen SI, Framstad T. Hematologic and biochemical reference intervals for Norwegian crossbreed grower pigs. *Vet Clin Pathol.* 2010;39:221-226. **https://doi.org/10.1111/j.1939-165X.2009.00199.x**

19. Cooper CA, Moraes LE, Murray JD, Owens SD. Hematologic and biochemical reference intervals for specific pathogen free 6-week-old Hampshire-Yorkshire crossbred pigs. *J Anim Sci Biotechnol.* 2014;5:5. **https://doi.org/10.1186/2049-1891-5-5**

20. Jazbec I. Klinično laboratorijska diagnostika [Clinical laboratory diagnostics]. *Veterinarska fakulteta.* 1990:82-106.

21. Golinar Oven I, Nemec Svete A, Hajdinjak M, Plut J, Štukelj M. Haematological profiles of pigs of different age in relation to the presence or absence of porcine reproductive and respiratory virus, porcine circovirus type 2 and hepatitis E virus. *Ital J Anim Sci.* 2022;21(1):1287-1296. **https://doi.org/10.1080/1828051X.2022.2107954**

22. Evans EW. Interpretation of porcine leucocyte responses. In: Feldman BF, Zinkl JG, Jain NC, Schalm OW, eds. *Schalm's Veterinary Hematology.* 5th ed. Lippincott Williams and Wilkins; 2000:411-416.

23. Lindholm-Perry AK, Kuehn LA, Wells JE, Rempel LA, Chitko-McKown CG, Keel BN, Oliver WT. Hematology parameters as potential indicators of feed efficiency in pigs. *Transl Anim Sci.* 2021;5(4):txab219. **https://doi.org/10.1093/tas/txab219**

24. Zang J, Chen J, Tian J, Wang A, Liu H, Hu S, Che X, Ma Y, Wang J, Wang C, Du G, Ma X. Effects of magnesium on the performance of sows and their piglets. *J Anim Sci Biotechnol.* 2014;5(1):39. **https://doi.org/10.1186/2049-1891-5-39**

25. Eppenstein R. Improved concrete outdoor runs in housing systems for growing-finishing pigs: Temporary access to pasture. In: Eppenstein R, Thanner S, eds. *Welfare and Environmental Impact of Organic Pig Production. A Collection of Factsheets.* Research Institute of Organic Agriculture FiBL; 2022:29-31. Accessed March 20, 2024. **https://www.fibl.org/fileadmin/documents/shop/1300-hb-power-en.pdf**