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Pathology Influencing Dead-on-Arrival and Euthanized-on-Arrival Pigs at a Packing Plant During the Summer and Evaluation of Associated Transit Factors

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Summary

A total of 3,176 transportation records, representing 498,281 pigs, delivered to a commercial swine processing facility (Triumph Foods, St. Joseph, MO) were evaluated in June 2026. Data compiled included transportation details such as travel distance and number of animals per load, among others. Additionally, weather data were extracted from a local National Weather Service observation station and aligned with delivery timelines. For 9 days, a subset of loads with dead-on-arrival (DOA) and euthanized-on-arrival (EOA) animals were selected and necropsies were performed on these animals. A total of 80 necropsies (28 DOA, 52 EOA) were performed, and gross pathology was recorded based on visual assessment. Reasons for euthanasia of EOA pigs included lameness (n = 34) or significant morbidity (EOA-morbid; n = 19), such as being laterally recumbent and unable to recover or demonstrating evidence of shock. Of the 28 DOA and 19 EOA-morbid animals, increased pericardial fluid (64%; 37%, DOA, EOA, respectively), cardiac petechiae (71%; 32%), lung consolidation (61%; 47%), degenerative fat and muscle changes (54%; 11%), lung edema (46%; 47%), lung adhesions (18%; 21%), bruising (18%; 16%), and chronic pericardial changes (18%; 21%) were observed. Of the 34 EOA animals euthanized for lameness, 53% had a broken bone (of pigs with broken bones, 44.4% femur, 44.4% humerus, 11.1% tibia and fibula). Transit factors associated with increased DOA included (all $P \leq 0.011$): head received, wind direction, wind speed, driveway duration, backfat, loin depth, and dew point. Transit factors associated with increased EOA included (all $P < 0.001$): head received, unload hour, unload duration, travel distance, and unload dew point. Transit factors associated with total transportation losses (TTL; sum of DOA and EOA) included (all $P \leq 0.022$): head received, wind direction, unload duration, gate to finish duration, travel distance, backfat, loin depth, and unload dew point. Based on the gross necropsy findings, all animals that were DOA/EOA-morbid had underlying heart and/or lung pathology. Of animals euthanized for lameness upon arrival, 53% had a broken

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bone leading to the euthanasia decision. The identified transit factors and underlying heart or lung pathology likely contribute to increased losses at the packing plant.

Introduction

Dead-on-arrival (DOA) and euthanized-on-arrival (EOA) pigs represent important animal welfare and economic concerns for the swine industry. Collectively, these losses can be defined as total transportation losses (TTL). Such losses have direct economic consequences for pork producers, as animals that die or require euthanasia upon arrival generate limited or no economic return despite the resources invested in raising them to market weight. DOA and EOA pigs also raise substantial welfare concerns, as affected pigs may experience severe stress and injuries that can necessitate humane euthanasia or result in death. Many factors can contribute to DOA and EOA, including those that affect pigs' ability to cope with stress and those that increase stress during transport. Poor health, respiratory or circulatory difficulties that limit heat dissipation, and a lower surface area-to-body weight ratio may decrease this capacity to cope with stress. Previous research has identified the amount of time pigs spend on the trailer as an important contributor to stress, with insufficient time to recover from loading being particularly important.[4] Research has shown that environmental conditions may further compound these effects, as both high and low environmental temperatures have been associated with increased incidence of DOA and EOA.[5]

While several studies have linked transportation factors to losses such as DOA and EOA, limited information is available to characterize pathology present in these animals upon arrival at the processing facility. Therefore, the objective of this investigation was to characterize the pathology associated with DOA and EOA pigs and identify transit-related factors associated with their incidence.

Procedures

A total of 3,176 loads, including 498,281 pigs, were evaluated in a 30-d study at Triumph Foods in St. Joseph, Missouri. On nine of these days, necropsies were performed on selected loads with DOA and EOA pigs. Transit factors routinely collected by the plant at the truck load level include: date, call-in time, gate time, trucker check-in time, start and unload times, miles, EOAs, DOAs, head received, yard dead (pigs resulting in mortality or euthanasia in lairage), total live and hot carcass weights for delivery, average pig live and hot carcass weights, average percent lean, backfat, loin depth, and general causes for EOA animals. TTL were also calculated as the sum of DOA and EOA.

Weather data were obtained at 5-min intervals from a nearby National Weather Service observation station (approximately 2.25 miles away). Variables collected included g time, temperature, dew point, relative humidity, heat index, wind direction, and wind speed. On days when necropsies were performed, selected loads containing DOA or EOA were observed during the unloading process, and general data was recorded to link the necropsy findings with the corresponding load-level data. Both DOA and EOA pigs

[4] Rioja-Lang, F. C., J. A. Brown, E. J. Brockhoff, and L. Faucitano. 2019. A review of swine transportation research on priority welfare issues: A Canadian perspective. Front. Vet. Sci. 6:36. doi:10.3389/fvets.2019.00036.

[5] Peterson, E., M. Remmenga, A. D. Hagerman, and J. E. Akkina. 2017. Use of temperature, humidity, and slaughter condemnation data to predict increases in transport losses in three classes of swine and resulting foregone revenue. Front. Vet. Sci. 4:67. doi:10.3389/fvets.2017.00067.

marked for necropsy were collected in a separate pen, and necropsies were performed at two time points each day.

Statistical analysis

A beta-binomial model was fit in R (version 4.5.1; R Foundation for Statistical Computing) using the glmmTMB package, with the proportion of pigs arriving as DOA, EOA, or TTL within load as the response, and transportation and weather factors as fixed effects. Numeric predictor variables were categorized into quartiles. Variable selection began with a univariable analysis, and variables with $P \leq 0.20$ were retained for further exploration in the multivariable model selection process. Following univariable screening, correlation between variables was evaluated and highly correlated variables were removed ($r > 0.50$), prioritizing the variable remaining as the most biologically meaningful for the research question. Multicollinearity assessment was performed using the check_collinearity function of the Performance package in R, with all remaining variables having an adjusted variance inflation factor of < 2.0. Manual backward stepwise selection was performed using the buildglmmTMB function from the buildmer package in R using the likelihood ratio test criterion for elimination, followed by manual reintroduction tests of variables previously excluded during backward model selection. This process was repeated independently for DOA, EOA, and TTL. Results are reported as estimated marginal means from the final model, and final model parameters were considered significant at $P < 0.05$.

Results and Discussion

During the 30-day period, 3,176 loads of pigs were delivered to the processing plant, representing a total of 498,281 pigs. Over this time, there were a total of 1,234 DOA pigs (0.25% of pigs arriving) and 1,304 EOA pigs (0.26%), representing a TTL of 2,538 pigs (0.51%). Additionally, there were 450 pigs that died or were euthanized in lairage (yard dead; 0.09%).

For the 80 necropsies performed, the breakdown of DOA and EOA are found in Table 1. Each EOA pig was assigned to one of two categories: euthanized due to significant morbidity, such as being recumbent and unable to recover or showing significant signs of shock (EOA-morbid) or euthanized due to lameness or being non-ambulatory (EOA-lame).

A total of 47 pigs were necropsied as DOA or EOA-morbid. In these animals, significant necropsy findings included petechiae on the outer surface of the heart in 26 pigs (20 of 28 DOA pigs, 71%; 6 of 19 EOA-morbid pigs, 32%). Twenty-five pigs (18 of 28 DOA pigs, 64%; 7 of 19 EOA-morbid pigs, 37%) had increased fluid in the pericardial sac. Nine pigs (5 of 28 DOA pigs, 18%; 4 of 19 EOA-morbid pigs, 21%) had visible chronic changes to the pericardium, including fibrous tissue deposition and adhesion to the surface of the heart. Eight pigs (3 of 28 DOA pigs, 11%; 5 of 19 EOA-morbid pigs, 26%) had a pale heart, and four pigs (1 of 28 DOA pigs, 4%; 3 of 19 EOA-morbid pigs, 16%) had visible changes to the coronary vessels. Seven pigs (3 of 28 DOA pigs, 11%; 4 of 19 EOA-morbid pigs, 21%) had signs of heart failure, observed as thinning of the ventricles of the heart.

For lung pathology, 26 pigs (17 of 28 DOA pigs, 61%; 9 of 19 EOA-morbid pigs, 47%) had areas of visible and palpable lung consolidation. Twenty-two pigs (13 of 28 DOA pigs, 46%; 9 of 19 EOA-morbid pigs, 47%) had visible lung edema upon necropsy. Nine pigs (5 of 28 DOA pigs, 18%; 4 of 19 EOA-morbid pigs, 21%) had lung adhe-

sions where lung lobes were either adhered to other lung lobes or to the inside of the ribs. Eight pigs (5 of 28 DOA pigs, 18%; 3 of 19 EOA-morbid pigs, 16%) had enlarged lymph nodes observed in the process of performing thoracic necropsies. Nine pigs (6 of 28 DOA pigs, 21%; 3 of 19 EOA-morbid pigs, 16%) had an increased amount of fluid in the thoracic cavity. Seventeen pigs (15 of 28 DOA pigs, 54%; 2 of 19 EOA-morbid pigs, 11%) had degenerative changes to the musculature, mainly noticeable petechiae and/or changes to the fat indicated by a change in color.

EOA-morbid pigs showed a much broader distribution of pathological findings, with no singular pathological finding reaching > 50%. The most consistent change observed with EOA-morbid pigs was lung consolidation and lung edema, both at 48%. Overall, the thoracic necropsies revealed the most common findings included cardiac petechiation, increased pericardial fluid, lung consolidation, lung edema, and, in DOA pigs, degenerative changes to muscle and fat.

For the EOA-lame animals, the majority (53%) had a broken bone, with most fractures occurring in either the humerus (44.4% of fractures) or the femur (44% of fractures), with two pigs observed with fractured tibia and fibula (11% of fractures). A total of 11 hematomas were observed, with 91% of those being associated with a bone fracture resulting in significant soft tissue bleeding and damage. Signs of arthritis were observed in the joints of 17.6% of pigs euthanized due to lameness, with 10 of 34 EOA-lame pigs (29%) having no identifiable gross abnormalities.

Several transit factors were associated with DOA, EOA, and TTL (Table 3; quartile values are presented in Table 2). For DOA, the following transit factors remained in the final model (all $P \leq 0.011$): head received, wind direction, wind speed, driveway duration, backfat, loin depth, and dew point. Transit factors associated with increased EOA included (all $P < 0.001$): head received, unload hour, unload duration, travel distance, and unload dew point. Transit factors associated with TTL included (all $P \leq 0.022$): head received, wind direction, unload duration, gate to finish duration, travel distance, backfat, loin depth, and unload dew point.

An increase in losses was observed as driveway duration (DOA), unload duration (EOA and TTL), and total duration from gate to the end of unloading (TTL). Conversely, a shorter travel distance from farm to plant was generally associated with greater ($P < 0.05$) EOA and compared to longer travel distances. Additionally, as the number of head on a trailer increased, losses decreased ($P < 0.05$). Moreover, an increase ($P < 0.05$) in losses was observed when backfat and loin depth increased. Likewise, an increase ($P < 0.05$) in losses was observed when the dew point increased. Wind in the first quartile (1.77 mph) and fourth quartile (15.62 mph) was associated with increased ($P < 0.05$) DOA. Wind out of the south and the east were associated with increased ($P < 0.05$) DOA compared to wind out of the West. For TTL, calm conditions (no wind) were associated with greater ($P < 0.05$) TTL compared with wind from the north or west. Pigs unloaded between midnight to 1 AM and 11 AM to 1 PM were associated with increased ($P < 0.05$) EOA compared with pigs unloaded beginning at 9 PM which had the lowest probability of EOA.

In conclusion, all pigs classified as DOA/EOA-morbid showed underlying heart and/or lung pathology based on visual gross necropsy findings. Of pigs euthanized for lameness upon arrival, 53% had a broken bone leading to the euthanasia decision. The identified transit factors and underlying heart or lung pathology likely contribute to increased losses at the packing plant.

Acknowledgments

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Table 1. Summary of necropsy findings of dead-on-arrival (DOA) and euthanized-on-arrival (EOA) pigs.[1,2]

Item	DOA (28 total)		EOA (52 total)		Total (80 total)	
Morbidity	n = 28		n = 19		n = 47	
Heart	Count	%	Count	%	Count	%
Petechiae of heart	20	71	6	32	26	55
Chronic changes to pericardium	5	18	4	21	9	19
Increased pericardial fluid	18	64	7	37	25	53
Pale heart	3	11	5	26	8	17
Changes to coronary vessels	1	4	3	16	4	9
Signs of heart failure	3	11	4	21	7	15
Lung						
Lung consolidation	17	61	9	47	26	55
Lung edema	13	46	9	47	24	51
Lung adhesions	5	18	4	21	9	19
Other						
Enlarged lymph nodes	5	18	3	16	8	17
Increased thoracic fluid	6	21	3	16	9	19
Degenerative changes to muscle/fat	15	54	2	11	17	36
Bruising	5	18	3	16	8	17
Lameness	---		n = 34		---	
Broken bone	---	---	18	53	---	---
Femur	---	---	8	44	---	---
Humerus	---	---	8	44	---	---
Tibia and fibula	---	---	2	11	---	---
Hematoma			11	32		
With break	---	---	10	91	---	---
Not with break	---	---	1	9	---	---
Signs of arthritis	---	---	6	18	---	---
Unknown	---	---	10	29	---	---

[1] A total of 3,176 transportation records were evaluated, representing 498,281 pigs delivered to Triumph Foods, a commercial swine processing facility, in June 2026. On nine of these days, necropsies were performed on selected loads with DOA (28) and EOA (52) pigs.

[2] Values reported are count of pigs with each specific post-mortem abnormality. Each animal may have had multiple abnormal findings; thus, they are not additive. One pig was considered EOA due to both morbidity and lameness.

Table 2. Descriptive statistics for variables selected for multivariable models for percent dead-on-arrival (DOA), euthanized-on-arrival (EOA), and total transportation losses (TTL).[1,2]

	Quartile			
Item	1	2	3	4
Head received, n	148.1	155.4	159.4	164.8
Driveway duration, min	4.6	8.6	14.0	26.0
Gate to finish duration, min	26.0	35.3	44.9	62.1
Travel distance, miles	183.1	259.6	281.2	322.7
Backfat, in	0.53	0.57	0.60	0.66
Loin depth, in	2.42	2.54	2.61	2.71
Unload dew point, °F	53.67	59.83	66.92	72.46
Wind speed, mph	1.77	6.03	8.74	15.62

[1] A total of 3,176 transportation records were evaluated, representing 498,281 pigs delivered to Triumph Foods, a commercial swine processing facility, in June 2026. The dataset consisted of transportation factors, weather data, and counts of pigs that were DOA or EOA.

[2] Total transportation losses (TTL = DOA + EOA).

Table 3. Summary of multivariable models for percent dead-on-arrival (DOA), euthanized-on-arrival (EOA), and total transportation losses (TTL).[1,2]

	Quartile				
Item	1	2	3	4	*P* =
DOA, %					
Head received	0.30 ± 0.035[c]	0.23 ± 0.028[b]	0.16 ± 0.021[a]	0.16 ± 0.021[a]	< 0.001
Driveway duration, min	0.20 ± 0.026[ab]	0.19 ± 0.024[a]	0.18 ± 0.024[a]	0.25 ± 0.029[b]	0.011
Backfat, in	0.17 ± 0.022[a]	0.18 ± 0.023[ab]	0.25 ± 0.030[c]	0.22 ± 0.030[bc]	< 0.001
Loin depth, in	0.15 ± 0.021[a]	0.21 ± 0.026[b]	0.21 ± 0.027[b]	0.25 ± 0.031[b]	< 0.001
Dew point, °F	0.15 ± 0.020[a]	0.15 ± 0.021[a]	0.24 ± 0.029[b]	0.31 ± 0.041[c]	< 0.001
Wind speed, mph	0.25 ± 0.031[b]	0.16 ± 0.022[a]	0.18 ± 0.025[ab]	0.24 ± 0.031[b]	0.001
Wind direction	See Figure 1				0.006
EOA, %					
Head received	0.32 ± 0.019[c]	0.22 ± 0.015[b]	0.20 ± 0.014[ab]	0.16 ± 0.013[a]	< 0.001
Unload duration, min	0.14 ± 0.012[a]	0.16 ± 0.013[ab]	0.21 ± 0.015[b]	0.43 ± 0.023[c]	< 0.001
Travel distance, miles	0.27 ± 0.017[b]	0.19 ± 0.014[a]	0.22 ± 0.015[ab]	0.19 ± 0.014[a]	< 0.001
Dew point, °F	0.18 ± 0.013[a]	0.19 ± 0.014[a]	0.25 ± 0.016[b]	0.26 ± 0.016[b]	< 0.001
Unload hour	See Figure 2				< 0.001
TTL, %					
Head received	0.68 ± 0.050[c]	0.51 ± 0.039[b]	0.42 ± 0.033[a]	0.35 ± 0.030[a]	< 0.001
Unload duration, min	0.31 ± 0.028[a]	0.37 ± 0.031[a]	0.52 ± 0.041[b]	0.85 ± 0.061[c]	< 0.001
Gate to finish duration, min	0.46 ± 0.038[ab]	0.42 ± 0.035[a]	0.48 ± 0.037[ab]	0.55 ± 0.042[b]	0.001
Travel distance, miles	0.55 ± 0.042[b]	0.46 ± 0.037[ab]	0.47 ± 0.037[ab]	0.42 ± 0.034[a]	0.002
Backfat, in	0.41 ± 0.033[a]	0.45 ± 0.035[a]	0.56 ± 0.041[b]	0.50 ± 0.042[ab]	< 0.001
Loin depth, in	0.43 ± 0.035[a]	0.47 ± 0.037[ab]	0.47 ± 0.037[ab]	0.54 ± 0.042[b]	0.022
Dew point, °F	0.37 ± 0.030[a]	0.40 ± 0.034[a]	0.52 ± 0.040[b]	0.67 ± 0.054[c]	< 0.001
Wind direction	See Figure 3				0.021

[1] A total of 3,176 transportation records were evaluated, representing 498,281 pigs delivered to Triumph Foods, a commercial swine processing facility, in June 2026. The dataset consisted of transportation factors, weather data, and counts of pigs that were DOA or EOA. Data reported as percentage of pigs resulting in DOA, EOA, and total transportation losses (TTL = DOA + EOA). Model adjusted mean ± SEM.

[2] Distance from farm to plant also included in final model as it substantially improved model fit, although P-value not statistically significant (P = 0.414).

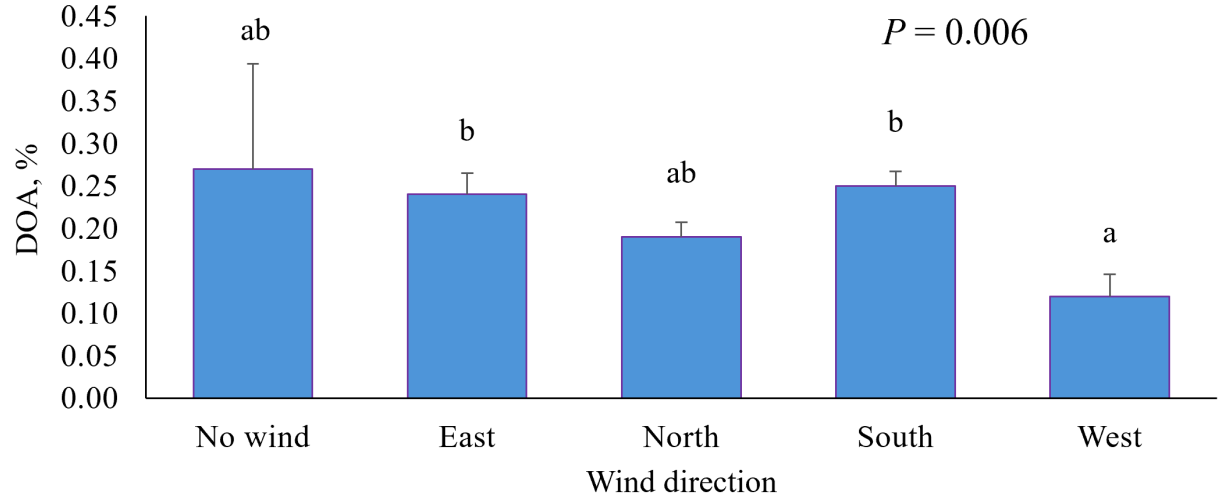


Figure 1. Probability of dead-on-arrival (DOA) by wind direction.

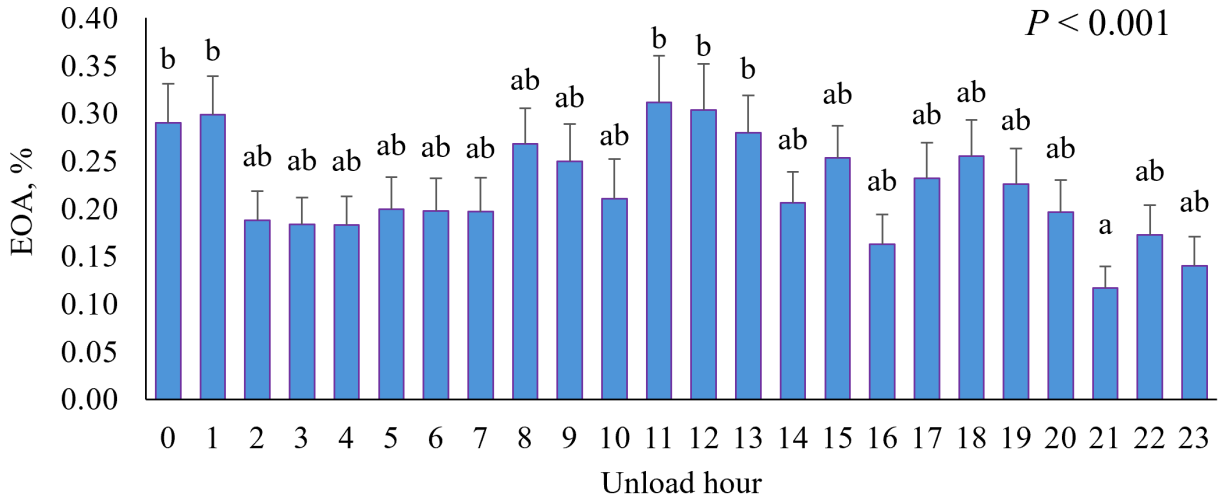


Figure 2. Probability of euthanized-on-arrival (EOA) by unloading start time.

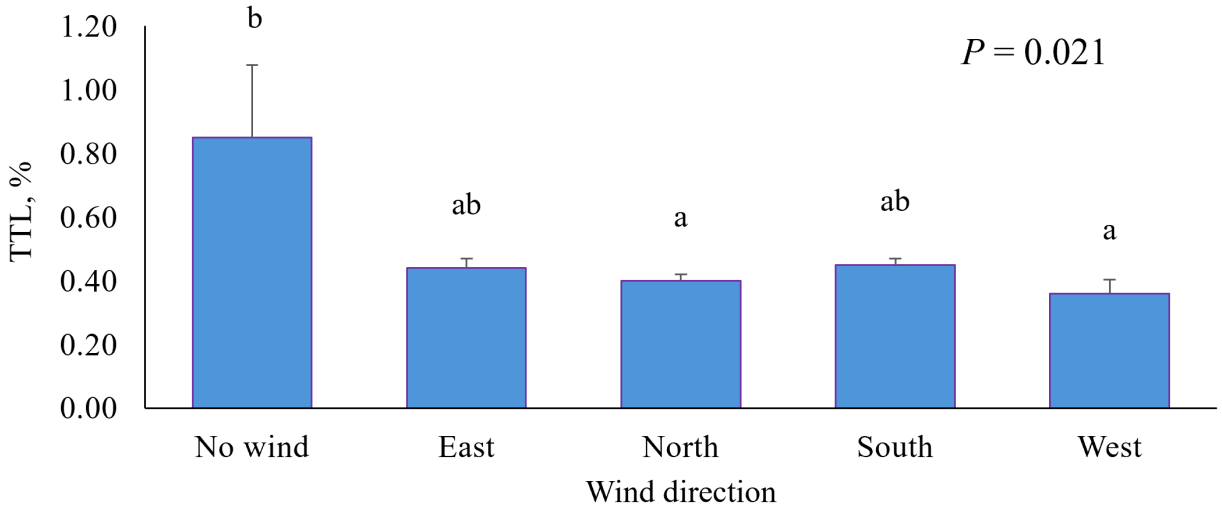


Figure 3. Probability of total transport loss (TTL; calculated as DOA + EOA) by wind direction.