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EVALUATION OF DIFFERENT MONITORING METHODS FOR *MUSCA DOMESTICA* L. 1758 (DIPTERA: MUSCIDAE) INDOOR POPULATION

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SUMMARY

The housefly *Musca domestica* is a cosmopolitan insect nuisance pest, also known as a carrier of numerous pathogens both to humans and animals. Animal farms, as a very important source of house flies, simultaneously allow for all stages of their development. Having vast quantities of constantly present manure, pig units represent perfect environment for house fly breeding. This fact, coupled with the known resistance to majority of available insecticides, creates difficulties in house fly control. The present study was performed to evaluate different types of monitoring methods for indoor use: (a) spot deposit records on the cardboard; (b) fly trappings by: glue coated cardboard; (c) sticky fly strips; (d) yellow sticky cards; (e) visual records of flies on the cardboard. This study provided a clear differentiation of efficacy/usefulness of the tested methods for various house fly densities. In animal breeding units or other areas with very abundant fly population, less sensitive methods (traps are less efficient) should be selected. For these circumstances, glued cardboard or yellow sticky cards should be chosen. The "more sensitive" methods, spot cards and sticky fly strips, should be used for lower abundance of the fly population. Except for this purpose, these highly sensitive methods should be selected also in the areas where the flies should not be tolerated at any density. Although the levels of the observed fly activity significantly differ from each other, in the majority of cases they depict the similar trend of the population dynamics and relative density. The only exception to the rule was the visual method, which could not reflect the changes in the population density in the current study.

Key words: *Musca domestica*, house fly monitoring, trapping, sticky traps, spot cards

Abbreviations: SDBW- spot deposit recording on the black-white patterned side and SDW on the white side of the cardboard; GCC- fly trapping by glue coated cardboard (black-white patterned side); SFS- fly trapping by sticky fly strips; YSC- fly trapping by yellow sticky cards; VBW- visual recording of alive flies resting on the black-white patterned side and VW- on white side of the cardboard.

INTRODUCTION

Musca domestica L. 1758 (house fly) is a non-biting cosmopolitan molestant, strongly associated with human habitation and recognized as a mechanical carrier of a variety of pathogens (Hewitt, 2011; Howard, 1911). Houseflies can transmit more than 100 pathogen species including 65 causative agents of human and animal diseases (Greenberg et al., 1970, 1971, 1973). The most important pathogens that affects pig production, as well as human health, include the following bacterial pathogens: *Shigella* sp., *Vibrio cholerae*, *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* sp., *Campylobacter* sp. etc (Levine & Levine, 1991; Crosskey & Lane, 1993; Meerburg et al., 2007; Agui, 2001; Graczyk et al., 2001; Navduch & Stutzenberger, 2001; Chavasse et al., 1999; Holt et al., 2007; Iwasa et al., 1999; Sasaki et al., 2000; Barber et al., 2002; Olsen & Hammack, 2000; Mian et al., 2002; Winfield & Groisman, 2003; Szalanski et al., 2004; Ekdahl et al., 2005).

Pig production could also be affected by fly-carried parasites *Cryptosporidium parvum* (Graczyk et al., 1999), *Toxoplasma gondii* (Graczyk et al., 2001; Wallace, 1971) and *Sarcocystis* spp. (Markus, 1980), as well as by gastroenteritis virus – TGEV (Saif & Wesley, 1999) and porcine reproductive and respiratory syndrome virus – PRRSV (Otake et al., 2003a, b). Fly-carried bacteria *Streptococcus suis* causes serious hazards by passing on the infection to farmers, butchers and abattoir workers, manifested as an septicaemia, meningitis, arthritis, pharyngitis and diarrhoea (Snashall, 1996). This bacteria caused an outbreak in China with 206 cases reported while 38 had fatal outcome (WHO, 2005).

Flies transmit pathogens to humans and animals through four central pathways: 1. mechanical transmission (by contact of the house fly body with different surfaces), 2. faecal deposition, 3. salivation (house fly has extra-oral digestion, they secrete saliva to liquefy solid food before feeding on it) and 4. regurgitation of incompletely digested food and reabsorption. Flies could collect pathogens on their body parts when females lay eggs on decomposing organic matter such as faeces, organic waste and animal corpses. *Musca domestica* usually breeds in animal droppings, manure piles, decaying silage, spilt feed, dirty bedding, and other moist, warm decaying organic matter. It is the most abundant insect associated with livestock, poultry, companion animals and inappropriate hygiene conditions in human environment.

At optimal temperature (25-35°C) a house fly female can produce up to six batches of 75 to 200 eggs at 3 to 4-day intervals. Development of house flies at each life stage is temperature-dependent. Under optimal summertime conditions, flies may complete their life cycle in a very short period, 7-8 days (Gerry et al., 2004). Overlapping of generations is very conspicuous in *M. domestica* development, and all stages are usually present at the same time when the food source is permanently available, such as in animal farms. Adult flies live for an average of 3 to 4 weeks, but they can live twice as long. They are most active during the daytime at temperatures of 27 to 32° C and become inactive at night and at temperatures below 7°C (Kaufman et al., 2000). Resting adults can be seen inside facilities on ceilings, walls, pillars and other surfaces. Their preferred resting places can be detected by accumulation of “fly specks”, which appear as light-coloured rounded spots formed from regurgitated fluid and darker, tailed spots of faecal droplets.

Control of house flies in a variety of farms (poultry, pig and dairy farms) and food processing industries is usually challenging to manage and requires application of elaborate measures (Hansens, 1963; Axtell & Arends, 1990; Ostrolenk & Welch, 1942). Flies can cause significant adverse effects on pigs’ growth performance. Flies disturb and irritate livestock and workers, cause financial loss by decreasing the production of farm animals (Campbell et al., 1977; Catangui et al., 1997), create a bad impression to visitors, and transmit infectious diseases to livestock and humans (Graczyk et al., 2001; Meerburg et al., 2007).

Given the critical role of livestock breeding in agricultural production and problems that flies cause, it is required to keep the fly population density under the threshold of noxiousness. Efficient and environmentally friendly management practices, including sanitation and control, are necessary to reduce the house fly population density. Improper and untargeted use of biocides and other products of the same purpose, combined with the house flies’ short life cycle (<7 days) (Larsen & Thomsen, 1940) and their high reproductive capacity could create conditions encouraging the rapid development of resistance to biocides. Extensive spraying of insecticides for house fly control resulted in widespread development of insecticide resistance (Chapman & Lloyd, 1981; Chapman et al., 1993; Keiding 1975, 1999; Shono et al., 2004).

Regardless of the types of measures applied for house fly control, chemical, biological control with fungal pathogens (Siri et al., 2005), parasitoids (Kaufman et al., 2001; Skovgård & Nachman, 2004; Skovgård & Steenberg, 2002) or insect sterilization (Howard & Wall, 1996), evaluation of the applied treatment effects is required. The adequate sampling method is crucial to indicate the existing fly activity.

A comprehensive sampling method, which should be based on the understanding of the species biology and environmental demands, could provide an insight into the seasonal and weather-related fly population changes. Today, there are many different sampling methods available for fly population monitoring. The most frequently studied methods for indoor monitoring are spot cards, sticky tapes, baited traps and baited jugs (Hogsette, 1993; Lysyk & Axtell, 1986, 1985; Stafford et al., 1988). Early laboratory studies on the response of *M. domestica* to visual stimuli stated that they preferentially land on black or red surfaces, and avoid blue or white (Hecht, 1963; Pospisil, 1962; Waterhouse, 1948). Studies conducted in weakly illuminated conditions of livestock breeding units showed that pale colours such as yellow or white were more attractive (Mitchell et al., 1975). Other authors stated that adequate visual contrasts were more attractive to house flies than the colour of the trap itself (Hecht, 1970; Howard & Wall, 1998). The findings on the efficiency of the monitoring methods for house flies and their response to different stimuli are often contradictory.

The selection of an appropriate house fly monitoring method depends on the breeding conditions and strengths/limitations of a particular approach. Also, a suitable monitoring method should consider medical and economic aspects. Methods with potentially harmful effects on humans and animals should be excluded. For practical reasons, the selected method should be easy to use, and it should require very little time investment.

The predicted increase of the house fly populations and incidences of vector-borne disease related to global warming (Goulson et al., 2005; Haines et al., 2006) require efforts to improve the fly control strategy. Some authors also suggest that house fly baits could be used as a management tool to reduce the adult fly number without compromising the monitoring value of spot cards (Gerry et al., 2011).

The objective of the present study was to evaluate the performance of the following house fly monitoring methods, designated for indoor use: (i) spot deposit recording on the black-white patterned side and on the white side of the cardboard; (ii) fly trapping by glue coated cardboard (black-white patterned side); (iii) fly trapping by sticky fly strips; (iv) fly trapping by yellow sticky cards; (v) visual recording of alive flies resting on the black-white patterned side and on white side of the cardboard. This study is aimed to ease the selection of the right monitoring tool.

MATERIAL AND METHODS

Breeding sites

The study was carried out on a pig farm with an indoor housing system, which refers to breeding pigs in confinement at high density. The farm was located in a rural area, the village of Sirig, in the northern part of Serbia (45°25'54.07"N 19°46'31.10"E). Four pig breeding units, in which monitoring methods were employed for the flies, represented four replicates. Each unit included all four types of monitoring methods, with the aim of indicating the most effective method.

Piglet cages were positioned on two sides of the breeding unit. Containers with food and water were placed in front of each cage. At the beginning of the fly monitoring process, 35 days old piglets had already been placed into the unit. They remained in the breeding units during the following 45 days. After that, they were transferred into units for older pigs. After the piglets had been moved out of the breeding units, the whole construction was cleaned. The structure of the breeding unit included two slurry/manure channels, positioned beneath the boxes with piglets. Once a week, the water was flushed through the channels, to avoid clogging. Cleaning and washing of the entire breeding unit, including removal of liquid manure, faecal and other organic matter was done between two breeding cycles, before the introduction of new piglets, which implies that complete cleaning was carried out at 80 days intervals. All surfaces were cleaned with phenolic disinfectant Environ™.

During the piglet breeding cycle, the process of removing the organic matter from the boxes was not done on a regular basis, providing optimal conditions for fly development and consequently increase of the fly population. In the breeding units selected for the study, there was an overflow or leak of food on the ground surface. Such conditions were suitable for egg-laying and further larvae development, followed by masses of eggs, larvae and pupae being recorded.

During the present study, the average temperatures and relative humidity in the breeding unit were recorded at 6 a.m. ($27.5 \pm 0.5^\circ\text{C}$), at 2-4 p.m. ($35.5 \pm 0.5^\circ\text{C}$) and 10 p.m. ($24.5 \pm 0.5^\circ\text{C}$). Relative air humidity was in the range of $65.5 \pm 0.5\%$. The temperature and humidity were changed and regulated according to piglets breeding requirements. Insecticide treatments of house flies were not conducted in the breeding units during the study.

Monitoring methods

All monitoring methods were tested in four replicates. Monitoring of adult flies was conducted by application of four different monitoring/trapping methods: (i) spot deposit recording on the black-white patterned side and the white side of the cardboard; (ii) fly trapping by glue coated cardboard (black-white patterned side); (iii) fly trapping by sticky fly strips; (iv) fly trapping by yellow sticky cards; (v) visual recording of alive flies resting on the black-white patterned side and on white side of the cardboard (Fig. 1).

Figure 1. Monitoring methods: A) spot deposit on the black-white patterned side, B) spot deposit on the white side, C) fly trapping by glue coated cardboard, black-white patterned, D) sticky fly strips, E) yellow sticky cards

Spot deposit was recorded on each of two face cardboards (20 × 20 cm), with black-white patterned and white side. The cardboards were covered with standard quality white paper. The paper on one side remained white (Fig. 1A), while on the other side there were black patterns on white background (Fig. 1B). Comparison of the number of landed flies, as well as the number of deposited spots by flies (faecal and salivation droplets) at two different sides of the cardboard, were used to observe the house fly preference for the offered resting places. The number of landed, alive flies referred to the counted specimens that were resting on each side of the cardboard at the moment of the check at each checking date, while the number of spots referred to deposited droplets accumulated on the cardboard during each monitoring interval.

The cardboards of the same design and size were coated by rat glue (No Rat, Polybutene isobutylene/butene copolymer, Kollant S.p.a. Vigonovo Italy) on their black-white side only for fly trapping by glue coated cardboard. Glue remained active during the whole monitoring interval. Glued adults were counted after monitoring interval ended and the cardboards were replaced by the new ones (Fig. 1C).

Commercial trapping product (Effect, Unichem doo, Slovenia), designed for reducing the number of adult flies, i.e. yellow, semitransparent, curly and double side sticky (60 x 4 cm), was used for fly trapping by sticky fly strips method (Fig. 1D).

Another commercial trapping product (Pinus, Slovenia) designed for monitoring of fruit flies (*Rhagoletis spp.*), bright yellow double side sticky cardboard (10 x 25 cm), was used for fly trapping by yellow sticky cards method (Fig. 1E).

Recording of alive flies, resting on the black-white patterned (VBW) and white side of the cardboard (VW) was conducted on cards with the same size and design as SDBW/SDW/GCC. The landing was recorded on the whole surface of both sides of the cardboard (black-white patterned and white side).

Evaluation of the applied monitoring methods was conducted during the morning hours (starting at 9 a.m. until noon). The monitoring was held throughout the summer season (end July to mid-September). During the study period, the evaluation of the applied monitoring methods was carried out nine times (on days 1, 4, 5, 8, 10, 11, 15, 22, and 29 after the set up of the methods). All methods were replaced with the new ones on the weekly basis, i.e. after seven days of exposure.

All monitoring methods were hung on the metal rods mounted transversely, 1 m above the piglet boxes, out of the reach of the animals (approximately at 2 m above the floor). The monitoring methods were placed randomly in four units to avoid the influence of micro-location.

In order to identify the fly species present on the farm, the samples of adults were collected during the experiment. The sampling was carried out by randomly collecting dead flies on floor. Live flies were not collected to avoid the impact on the real fly population density in the breeding units. Flies captured by the sticky traps were not included in identification because of setae damage caused by the adhesives. Adults were collected in a plastic dish and brought to the laboratory for identification of species. The morphological identification of species was done according to the dichotomous identification key (D'Assis Fonseca, 1968).

Statistical analysis

The data analysis was performed using statistical program Dell Inc. (2016) Statistica (data analysis software system), version 13.6 (available at www.statsoft.com).

Spots on the cardboards were counted by Spotter© software (© 2019 Regents of the University of California, <https://ucanr.edu/sites/flyspotter/download/>). Fly or spot index (number of flies or spots per day) were calculated. The fly number and the number of spots on the cardboards were log (N+0.5) transformed. The significant differences

of device efficiency among all monitoring methods, based on counted glued flies, counted spots on the cardboards and landed flies records, was compared using Duncan's Multiple Range Test.

Multiple regression models were used to estimate the house fly population trend based on the numbers of spots or flies, recorded on the day of evaluation. The trend of *M. domestica* population density in the experimental breeding unit was assessed based on the data obtained by using all monitoring methods. The slopes of the regression lines for each monitoring method were produced. The methods grouped according to the level of efficiency for flies.

Homogeneity of the slopes model was used to compare the slope coefficients for all of the monitoring methods. Fly or spot index was used as a dependent variable and the days of inspection as a continuous predictor.

RESULTS AND DISCUSSION

All of the collected and identified fly specimens belonged to a single species, *M. domestica*. Based on statistical analysis of the obtained monitoring results, the seven applied monitoring methods could be classified into four distinct groups as presented in Table 1 (numbers of fly population indicators are given in Table 3).

Table 1 Mean number of spots or flies recorded by different monitoring methods during the study period (eight weeks)

Group	Monitoring methods	Mean spots or flies number	+/- SE
a	Patterned target	119.01 a	14.47
a	White target	110.26 a	15.52
b	Glue coated target	20.06 b	3.27
a	Fly strip	107.61 a	22.98
c	Yellow sticky card	15.72 c	3.46
d	Visual index on patterned target	0.85 d	0.28
d	Visual index on white target	0.65 d	0.21

* means followed by the same letter are not significantly different

The highest average values were recorded by counting the spots deposited by the resting flies at both black-white patterned and white sides of two-faced cardboards, as well as by recording the number of flies trapped on sticky fly strips (group A). Significantly lower counts were obtained by catching the adults by application of glue coated cardboards (group B), yellow sticky cards (group C). The lowest average values were recorded by counting of alive flies resting on the black-white patterned and white side of the cardboard (group D).

An average numbers of the spots deposited by adult flies on the black-white patterned and white side of two-faced cardboards were not significantly different ($p = 0.436$). Similarly, the number of visually recorded flies resting on different sides of the two-faced cardboard did not show a significant difference ($p = 0.398$). The number of the flies recorded by sticky fly strips was lower but not significantly different from the number of spots deposited by the flies on both black-white patterned ($p=0.073$) as well as from the white side of the two-faced cardboards ($p=0.264$).

Significantly higher average number of flies was recorded on sticky fly strips compared to the application of the two other sticky monitoring methods (glue coated cardboards and yellow sticky cards). Furthermore, the glue-coated cardboards sampled a significantly higher number of flies than yellow sticky cards ($p=0.002$). Visual monitoring methods, VBW and VW, resulted in the lowest average number of flies, with high statistical significance ($p=0.000$).

Regression of the house fly population density obtained by all monitoring methods, except the visual method, showed no difference (Tab. 2).

Table 2. Regression parameters for different monitoring methods

Monitoring methods	b*	SE of b*	b	SE of b	t (34)	p-value
Patterned target	0.01	0.17	<0.00	0.00	0.08	0.938
White target	0.05	0.17	0.00	0.01	0.27	0.792
Glue coated target	-0.24	0.17	-0.01	0.00	-1.44	0.159
Fly strip	-0.10	0.17	<0.00	0.01	-0.59	0.561
Yellow sticky card	0.18	0.17	0.01	0.01	1.04	0.304
Visual index on patterned target	-0.61	0.14	-0.03	0.01	-4.54	<0.001
Visual index on white target	-0.47	0.15	-0.02	0.01	-3.14	0.004

Table 3. Mean spot or fly number per day (index) on tested monitoring methods

Monitoring methods	Monitoring days							
	1	4	5	8	11	15	22	29
Patterned target	191.00±5.80	44.08±9.59	121.75±3.64	136.92±45.3	160.75±13.90	73.44±18.48	111.71±4.16	120.96±7.56
White target	192.00±10.30	25.17±2.47	98.75±20.07	155.17±30.4	132.50±10.82	94.81±17.88	92.89±12.55	105.79±9.97
Glue coated target	28.50±4.63	10.83±1.73	37.50±9.53	13.83±2.11	22.25±2.36	8.06±1.05	12.61±2.12	18.93±0.94
Fly strip	263.00±32.85	33.75±4.46	97.25±27.86	148.67±27.9	91.75±17.80	62.06±9.86	51.11±9.67	133.75±24.64
Yellow sticky card	39.25±6.55	2.58±0.92	12.75±3.82	12.42±1.86	17.25±5.86	16.94±5.09	13.21±2.42	20.46±3.48
Visual BW target	2.75±0.25	0.92±0.34	1.50±0.50	0.50±0.10	0.75±0.25	0.56±0.12	0.21±0.04	0.18±0.07
Visual W target	2.25±0.63	0.83±0.40	0.75±0.25	0.33±0.14	0.50±0.29	0.44±0.12	0.18±0.04	0.21±0.09

The homogeneity of the slopes was analyzed for the spot deposit method (SDBW and SDW) and all methods employing glue. There was homogeneity between the slopes of the compared monitoring methods in each compared combination (no significant differences, $p > 0.05$ in all combinations).

The comparison of the slopes of both visual methods (VBW and VW) with other monitoring methods showed no homogeneity. However, there was homogeneity of the slopes between VBW and VW monitoring methods.

The results obtained by the visual methods showed no significant difference ($p = 0.216$ and $p = 0.694$). According to the number of counted flies and spots, the population density was decreasing during the experiment.

In this study we evaluated the performance of seven different house fly monitoring methods: (i) spot deposit recording on the black-white patterned side and the white side of the cardboard; (ii) fly trapping by glue coated cardboard (black-white patterned side); (iii) fly trapping by sticky fly strips; (iv) fly trapping by yellow sticky cards; (v) visual recording of alive flies resting on the black-white patterned side and on white side of the cardboard. The study depicts potential usage of these relative methods for population size estimation in an indoor farm breeding unit, where the house fly was the primary species molesting the pigs. Using different patterned/coloured cardboards, we found no difference in attraction between black-white patterned and white side of the two-faced cardboards. Our hypothesis based on earlier research results (Nicholas, 1988; Richter et al., 1976) that the black-white pattern induces higher attractiveness was not confirmed. One possible explanation is that the design of the black-white patterned side was in competition to the metal grids of the piglets' box construction, hence it did not stand out in such environment. Studies of Richter et al. (1976) and Nicholas (1988) in laboratory conditions demonstrated that a regularly spaced pattern of black spots on white background enhanced the visual attraction of *M. domestica* compared to the solid white. Chapman et al. (1999) contradicted the stated results showing that such a design as well as longitudinal black stripes did not induce better attraction of house flies than a white carton. They recorded the highest efficiency on the visual pattern of clustered black spots. However, Hanley et al. (2009) showed that neither the use of different colours (including yellow) nor the clustered house flies resulted in significantly increased attraction.

Food that has already been fed on by *M. domestica* becomes progressively more attractive due to the substance termed "fly factor" (probably an aggregation pheromone) by Barnhart & Chadwick (1953) and Dethier (1955). This phenomenon has recently been confirmed by Holl & Gries (2018). The visual stimulation of black adults grouped into tight clusters might further promote attractiveness, as clustered groups of flies are described as the principle visual cue involved in location of food resources (Wiesmann, 1962, 1960).

We observed that the increase in the number of *M. domestica* at both the SDBW and SDW coincided with augmentation of the faecal spot number per checking interval. The increase might be caused by both growth in the number of adult flies on the farm and increased attractiveness of our cardboard. Unfortunately, our experiment was not designed to check for increased attractiveness that could contribute to the estimation of the quality of the monitoring methods.

Mitchell et al. (1975) found that white targets were very attractive to the house flies. In our study, a vast number of faecal spots was recorded on both the black-white patterned and white side of the spot cardboards, which implies high attraction for the flies (Table 3). It should be noted that house flies can dispose faeces several times on the same surface and that the number of spots could not be straightforwardly translated as the number of flies.

Hecht et al. (1968) found that the most attractive colour to *M. domestica* in grey surrounding of the dairy shelter was yellow. They found that contrast with the surroundings is more important than the colour itself (Hecht, 1970). DiClaro et al. (2012) disagreed with Hecht et al. (1968) results because their experiments demonstrated that yellow was significantly less attractive, verging on being repellent to house flies. Their findings also showed that yellow color was less attractive as a solid color in comparison to white or blue and as lines on blue background. The addition of a black line pattern enhanced the attractiveness of blue visual targets, whereas yellow lines decreased its attractiveness.

The Geden (2006) showed that blue fabric targets were more visually attractive to house flies than white and black fabric targets. Diclaro et al. (2012) found out that house flies may perceive the blue visual target as a potential resting area and the black lines as cracks or crevices that flies use as harbourage. Fattah (2011) found the most attractive color to house flies was black. Our findings showed that applied yellow cards were not highly attractive to house flies compared to differently colored methods (SDBW, SDW and SFS).

Spot cards in the present study were conspicuous in their surrounding, which is supported by a large number of spots on each side of spot card, although there were no significant differences between two different patterned sides.

Lysyk & Axtell (1986) found that fly activity measured using spot cards was correlated with activity measured using fly sticky tapes/strips. We obtained similar results for all except for the visual monitoring methods. Also, we found no significant differences between fly activity measured by the number of spots (SDBW and SDW) and by sticky strips (SFS). Although SDBW, SDW and SFS provided higher numbers of the fly population density than the GCC and YSC methods, they all depicted a similar tendency.

Birkemoe & Sverdrup-Thygeson (2011) determined the house fly population density by using the visual index which measures the number of flies near pigs during the count. Their method was similar to our visual method, except that in their study there was a larger surface for recording the flies' landing. The visual method we used did not provide satisfying results, which might be influenced by a very small surface for landing during a short period. It is also true that house flies are found at higher densities adjacent to animals and breeding resources than elsewhere in dairy farms (Black & Krafur, 1985). Accordingly, it might be useful to test the attractiveness of the cardboards for recording of landed flies placed close to and further from the pigs or other animals in the farm.

Chapman et al. (1999) suggested that chemical stimuli were more important than visual in resource location, but the addition of chemicals will require further standardization and raise the price of the monitoring program. Use of improper substances might also cause harmful effects on livestock health.

Skovgård (2004) calculated the threshold level of fly nuisance for Danish pig farms and established the figure of twenty-five house flies per adult animal. The threshold level for the spot card monitoring method in Pennsylvanian poultry and dairy cattle farms was 100 spots per card (12.7 cm x 7.6 cm) per week (Kaufman et al., 2000, 2001; Rutz et al., 2000; Rutz & Waldron, 2016). Rutz & Waldron (2016) estimated thresholds for organic dairies when sticky strips are used (250 flies/strip/week).

Recalculated to the dimensions of our spot cards, the threshold would be 414 spots per card/week. The average weekly number of spots per card in our study was 833.09 on SDWB and 771.81 on SDW. According to the Rutz & Waldron (2016) estimations for fly strips, the number of house flies in our study site (farm) exceeded the threshold. The average number of flies/strip /week was 753.25.

Birkemoe & Sverdrup-Thygeson (2011) compared three different monitoring methods (spot cards, sticky traps and visual index- measuring the number of flies) on a pig farm. These authors claim that thresholds should be relied on only when the monitoring methods are strictly standardized. Birkemoe & Sverdrup-Thygeson (2011) also emphasize the need for studies on more precise density estimation such as mark-release-recapture, and comparison of results obtained by different monitoring methods. This should provide a basis for development of a conventional, standardized method for monitoring of various fly species. Considering the critical importance of house flies, the standardized methods for monitoring and thresholds estimation are emphasizing the need for implementation of sound and efficient fly control.

CONCLUSION

Considering the similarities in seasonal dynamic trends of house flies determined by all used methods, we suggest specific usage of different monitoring methods according to "sensitivity" (the number of indications of fly presence recorded – flies and spots). This practical division relies on reasoning based mainly on sensitivity, accuracy and working power saving. The "less sensitive" methods should be selected when the fly population in the animal breeding units or other areas is very abundant. For these circumstances, glued cardboard or yellow sticky cards should be selected. Although these traps are less efficient than the other methods, they could provide accurate information about the house fly population dynamics. Both methods had an acceptable level of precision for regular house fly monitoring. The main disadvantage is that the traps lose their effectiveness as the glue becomes less active so it should be replaced in the period determined for a specific location. The "more sensitive" methods, spot cards and sticky fly strips, should be used if the fly population abundance is not very high. Except for this purpose, these highly sensitive methods should be selected also in the areas where the flies must not be tolerated at any density, such as restaurants, food processing facilities etc. More sensitive methods are problematic when there is high fly

activity. Usage of “more sensitive” methods in breeding units when the high population density is recorded may fail to accurately reflect the fly activity. Also, the required handling time prolongs the monitoring procedure. Although the levels of the observed fly activity significantly differ, in the majority of cases they depict the similar trend of the population dynamics. The only exception was the visual method, as this method could not reflect the changes in the population density in the current study.

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