






## SUPPLEMENTARY MATERIAL

### The productivity of dairy cows on farms using milking robots – based on data from the Podlaskie Voivodeship

Zbigniew Skibko\*<sup>1)</sup> , Waław Romaniuk<sup>2)</sup> , Stanisław Winnicki<sup>3)</sup> ,  
Maciej Kuboń<sup>4)</sup> , Andrzej Borusiewicz<sup>5)</sup> 

<sup>1)</sup> Białystok University of Technology, Faculty of Electrical Engineering, Wiejska St, 45 D, 15-351 Białystok, Poland

<sup>2)</sup> Institute of Technology and Life Sciences – National Research Institute, Hrabska Al., 3, 05-090 Raszyn, Falenty, Poland

<sup>3)</sup> Retired professor

<sup>4)</sup> University of Agriculture in Kraków, Faculty of Production and Power Engineering, Department of Production Engineering, Logistics and Applied Computer Science, Mickiewicza Al., 21, 31-120 Kraków, Poland

<sup>5)</sup> International Academy of Applied Sciences in Łomża, Studencka St, 19, 18-402 Łomża, Poland

\* Corresponding author

**Table S1.** Number of dairy cows in herds milked by robots in the Podlaskie Voivodeship in 2019–2024

No. of herd	Number of dairy cows (head) per year					
	2019	2020	2021	2022	2023	2024
1	130	73	84	101	126	134
2	213	217	125	143	120	132
3	130	128	74	69	80	83
4	140	146	191	214	252	282
5	161	156	221	230	95	93
6	75	59	135	140	99	108
7	117	73	152	146	70	81
8	225	114	58	74	225	232
9	59	221	160	81	136	142
10	77	60	72	67	149	154
11	166	97	64	156	85	97
12	170	51	110	73	74	69
13	228	173	219	201	70	72
14	151	238	60	65	164	155
15		144	200	166	75	75
16			65	236	216	232
17			175	66	63	54
18			168	124	154	231
19			245	239	231	113
20			139	75	102	133

No. of herd	Number of dairy cows (head) per year					
	2019	2020	2021	2022	2023	2024
21				169	243	162
22				173	83	176
23				235	157	77
24				118	176	238
25					77	74
26					233	76
27					136	127
28					88	99
29						88
30						64
31						84
32						85
33						62
34						77
35						81
36						67
<b>Statistical values</b>						
Total	2 042	1 950	2 717	3 361	3 779	4 309
Average	145.86	130.00	135.85	140.04	134.96	119.69
Median	145.5	128	137	141.5	123	95
Maximum	228	238	245	239	252	282
Minimum	59	51	58	65	63	54
Range	169	187	187	174	189	228
Standard error	14.34	16.11	13.58	12.66	11.58	9.92
Standard deviation	53.67	62.40	60.71	62.04	61.30	59.54
Sample variance	2 880	3 894	3 686	3 849	3 757	3 545
Kurtosis	-0.73	-1.04	-1.24	-1.30	-0.91	0.68
Skew	0.01	0.40	0.20	0.28	0.66	1.25
Confidence level (95.0%)	30.99	34.56	28.41	26.20	23.77	20.15

Source: own study.

**Table S2.** Average performance of dairy cows in robot-milked herds in the Podlaskie Voivodeship in 2019–2024

No. of herd	Average herd milk yield (kg per herd per year)					
	2019	2020	2021	2022	2023	2024
1	9 401	9 613	10 966	11 611	11 962	12 653
2	10 599	10 532	8 559	9 197	8 465	9 792
3	10 844	10 255	9 380	8 632	9 591	9 894
4	10 537	10 053	10 299	11 621	11 389	11 636

No. of herd	Average herd milk yield (kg per herd per year)					
	2019	2020	2021	2022	2023	2024
5	9 073	9 740	10 363	9 612	11 140	11 526
6	9 972	10 754	10 324	10 293	9 776	9 962
7	9 463	10 172	10 284	10 496	9 770	10 971
8	12 343	10 231	10 509	10 888	8 894	10 386
9	12 359	12 984	9 360	10 278	11 793	11 654
10	10 982	12 215	9 899	10 102	11 691	12 133
11	12 265	10 933	9 712	9 164	11 407	12 067
12	9 108	9 091	9 956	10 912	10 846	12 011
13	10 514	12 382	11 974	10 102	10 307	10 985
14	9 463	10 873	11 934	10 388	9 464	10 944
15		10 054	9 070	8 949	11 011	11 321
16			9 565	11 408	9 917	10 765
17			12 810	11 442	9 114	10 763
18			8 814	10 962	8 657	12 110
19			10 477	8 255	11 751	11 825
20			10 288	9 445	10 903	11 378
21				12 736	8 345	13 731
22				9 119	9 437	10 053
23				11 118	12 554	9 912
24				9 833	9 726	11 321
25					8 707	10 939
26					11 433	10 592
27					9 376	10 159
28					10 090	10 732
29						10 222
30						11 935
31						13 285
32						10 656
33						10 367
34						10 708
35						12 012
36						10 981
<b>Statistical values</b>						
Average	10 494.5	10 658.8	10 227.15	10 273.46	10 268.43	11 177.25
Median	10 525.5	10 255	10 286	10 285.5	10 003.5	10 976
Maximum	12 359	12 984	12 810	12 736	12 554	13 731
Minimum	9 073	9 091	8 559	8 255	8 345	9 792
Range	3 286	3 893	4 251	4 481	4 209	3 939
Standard error	313.97	281.62	239.72	225.14	228.11	158.08

No. of herd	Average herd milk yield (kg per herd per year)					
	2019	2020	2021	2022	2023	2024
Standard deviation	1 174.76	1 090.73	1 072.06	1 102.95	1 207.04	948.48
Sample variance	1 380.052	1 189.689	1 149.315	1 216.492	1 456.955	899.615
Kurtosis	-0.94	0.29	0.70	-0.38	-1.18	0.36
Skew	0.52	0.95	0.82	0.15	0.11	0.71
Confidence level (95.0%)	678.28	604.03	501.74	465.73	468.04	320.92

Source: own study.

**Table S3.** Average milk fat yield in herds of dairy cows milked by robots in the Podlaskie Voivodeship in 2019–2024

No. of herd	Average fat yield (kg per herd per year)					
	2019	2020	2021	2022	2023	2024
1	397	398	435	441	487	487
2	413	437	378	373	361	411
3	433	419	391	363	392	399
4	424	415	435	473	473	478
5	348	381	424	395	438	445
6	392	446	427	423	393	409
7	389	410	424	437	412	440
8	463	429	441	445	378	422
9	461	496	389	427	480	470
10	429	448	423	404	459	500
11	462	400	424	373	464	492
12	367	361	413	453	443	467
13	411	459	465	408	405	431
14	380	420	460	420	385	440
15		410	370	382	445	482
16			379	442	411	440
17			500	444	376	444
18			373	438	365	477
19			412	342	455	469
20			439	395	431	450
21				493	342	502
22				380	396	412
23				430	478	397
24				417	400	434
25					352	430
26					442	436
27					391	440
28					412	435

No. of herd	Average fat yield (kg per herd per year)					
	2019	2020	2021	2022	2023	2024
29						424
30						485
31						496
32						424
33						408
34						416
35						480
36						437
<b>Statistical values</b>						
Average	412.07	421.93	420.10	416.58	416.64	447.47
Median	412	419	424	421.5	411.5	440
Maximum	463	496	500	493	487	502
Minimum	348	361	370	342	342	397
Range	115	135	130	151	145	105
Standard error	9.57	8.50	7.51	7.41	7.85	5.13
Standard deviation	35.82	32.93	33.60	36.29	41.55	30.76
Sample variance	1 282.8	1 084.5	1 129	1 317.3	1 726.5	946.1
Kurtosis	-0.75	0.91	0.24	-0.23	-1.04	-1.10
Skew	-0.04	0.39	0.40	-0.08	0.06	0.25
Confidence level (95.0%)	20.68	18.24	15.73	15.33	16.11	10.41

Source: own study.

**Table S4.** Average milk protein yield in herds of cows milked by robots in the Podlaskie Voivodeship in 2019–2024

No. of herd	Average protein yield (kg per herd per year)					
	2019	2020	2021	2022	2023	2024
1	339	331	385	394	417	444
2	361	363	315	326	290	355
3	374	355	317	291	322	351
4	357	344	364	405	398	414
5	348	317	359	331	386	395
6	331	362	361	358	339	341
7	331	352	358	363	343	380
8	395	359	368	382	301	361
9	384	421	310	349	411	415
10	382	375	344	339	404	437
11	408	364	338	291	409	424
12	314	310	351	368	370	422
13	355	417	399	342	348	384

No. of herd	Average protein yield (kg per herd per year)					
	2019	2020	2021	2022	2023	2024
14	327	361	378	352	306	372
15		337	317	317	371	389
16			331	374	344	382
17			439	374	323	385
18			315	373	301	407
19			352	290	388	401
20			354	321	364	399
21				429	296	467
22				317	326	356
23				376	417	346
24				335	340	397
25					297	382
26					388	366
27					319	353
28					349	386
29						362
30						432
31						429
32						363
33						348
34						371
35						415
36						385
<b>Statistical values</b>						
Average	357.57	357.87	352.75	349.87	352.39	389.333
Median	356	359	353	350.5	346	385
Maximum	408	421	439	429	417	467
Minimum	314	310	310	290	290	341
Range	94	111	129	139	127	126
Standard error	7.49	7.93	7.21	7.38	7.79	5.21
Standard deviation	28.02	30.73	32.25	36.16	41.22	31.26
Sample variance	785.34	944.41	1039.78	1307.51	1699.43	977.49
Kurtosis	-0.87	0.79	1.30	-0.29	-1.29	-0.41
Skew	0.25	0.72	0.88	0.11	0.12	0.48
Total	5006	5368	7055	8397	9867	14016
Confidence level (95.0%)	16.18	17.02	15.09	15.27	28	10.58

Source: own study.