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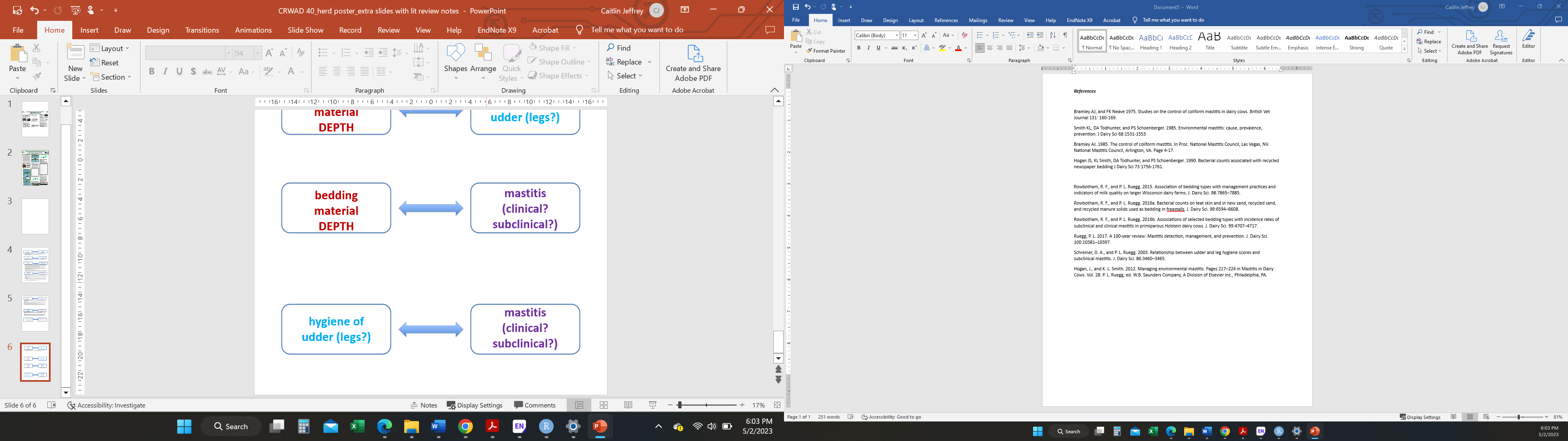
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**Cow-level hygiene, cow-level SCC or IMI:**

* **Schreiner, D. A., and P. L. Ruegg. 2003. Relationship between udder and leg hygiene scores and subclinical mastitis. J. Dairy Sci. 86:3460–3465.**
  + Objective of this study was to determine the relationship between udder and leg hygiene scores of lactating dairy cattle and measures of subclinical mastitis
  + Make the distinction of showing dirty cows actually = IMI, not just increased somatic cell count (although this study did both)
  + **Linear somatic cell scores increased as udder hygiene score increased** (significant differences between all contrasts of udder hygiene groups except 1 vs. 2, 3 vs. 4)
  + **Significant association between prevalence of intramammary contagious pathogens and udder hygiene score** (2.8% for 1, 4.7% for 2, 5.1% for 3, 7.4% for 4)
  + **Significant association between prevalence of intramammary environmental pathogens and udder hygiene scores** (9.7% for 1, 9.6 % for 2, 12.1% for 3, 13.8% for 4)
  + **Cows with udder hygiene scores of 3 and 4 were 1.5 times more likely to have major pathogens isolated from milk samples compared with cows with hygiene scores of 1 and 2**
  + Cows in freestall farms (8)
  + Observational
  + *“The presence of mastitis pathogens on teat ends has been correlated with the incidence of IMI (Pankey, 1989). Moisture, mud, and manure present in the environment of the cow are the primary sources of exposure for environmental mastitis pathogens, and hygiene scores of cows provide visible evidence of exposure to these potential sources. In this study, we were able to confirm the relationship between the measures of subclinical mastitis and measurements of animal hygiene”*
    - Shows dirty teat ends = mastitis, dirty teat ends = dirty udder
* **Reneau, J.K., Seykora, A.J., Heins, B.J., Endres, M.I., Farnsworth, R.J., F. Bey, R., 2005. Association between hygiene scores and somatic cell scores in dairy cattle. Journal of the American Veterinary Medical Association 227, 1297–1301**
  + The SCC of cows with cleaner udders and lower rear legs was lower than SCS of cows with dirtier udders and legs
  + Significantly increased SCS as hygiene scores of udders and lower rear legs increased from 1 (clean) through 5 (very dirty)
  + Cows in tiestall (1 farm) and freestalls (7 farms)
  + Observational
* **Sant’Anna, A.C., Paranhos Da Costa, M.J.R., 2011. The relationship between dairy cow hygiene and somatic cell count in milk. Journal of Dairy Science 94, 3835–3844**
  + The objectives of this study were to describe how the hygiene conditions of dairy cows vary over time and to assess whether a relationship exists between hygiene and somatic cell count (SCC) in milk. Monthly hygiene evaluations were conducted on lactating cows in 2 dairy farms for 9 consecutive months, totaling 3,554 evaluations from 545 animals. Hygiene was measured using a 4-point scoring system (very clean, clean, dirty, and very dirty) for 4 areas of the animal’s body (leg, flank, abdomen, and udder) and **combining these scores to generate a composite cleanliness score**. **The very clean cows had the lowest SCLS, followed by the clean, dirty, and very dirty cows (no statistically significant differences were found between the latter 2 groups)**
  + Cows housed in outdoor pens and paddocks
  + Observational
* **Devries, T.J., Aarnoudse, M.G., Barkema, H.W., Leslie, K.E., Von Keyserlingk, M.A.G., 2012. Associations of dairy cow behavior, barn hygiene, cow hygiene, and risk of elevated somatic cell count. Journal of Dairy Science 95, 5730–5739**
  + Explains factors as to why cows were dirtier, too
    - Less frequent scraping of the barn alleys was associated with cows having poorer hygiene
    - Poor udder hygiene was associated with poor stall hygiene.
    - Longer lying duration was associated with poor hygiene of the upper legs/flank and udder.
    - Greater pre-milking standing duration was associated with poor udder hygiene
    - Decreased frequency of lying bouts was associated with poor hygiene of the lower legs.
    - Higher milk yield was associated with poor hygiene of the udder and lower legs; multiparous cows had poorer hygiene of the upper legs/flank and udder.
  + Freestall
  + Experimental study (only one so far)
  + *“Over the study period, 24 new cases of elevated SCC were detected. No associations existed for the risk of experiencing an elevated SCC with alley scraping frequency or cow behavior patterns”*
    - *“the effect that barn alley floor hygiene has on cow SCC is likely dependent on whether or not that hygiene also has an effect on the hygiene of the stalls that cows are lying in”*
    - They manipulated alley scraping frequency as their treatment; no effect at that level, but was an association between STALL cleanliness and elevated SCC
* **de Pinho Manzi M, Nóbrega DB, Faccioli PY, Troncarelli MZ, Menozzi BD, Langoni H. Relationship between teat-end condition, udder cleanliness and bovine subclinical mastitis. Res Vet Sci. 2012 Aug;93(1):430-4.**
  + Teat-level: Although IMI cases tended to increase with a higher UC score, the effect of UC score was not statistically significant
  + Cow-level: There was a positive effect between the increase in UC score and the presence of IMI at the animal level
  + Relationship disappeared for SCC though: Even with low SCC (Table 4) for UC score 3 when compared to the remaining ones, there was no difference (P = 0.083) between SCC in the different udder cleanliness scores when the farm effect was controlled
* **Breen, J. E., M. J. Green, and A. J. Bradley. 2009. Quarter and cow risk factors associated with the occurrence of clinical mastitis in dairy cows in the United Kingdom. J. Dairy Sci. 92:2551–2561.**
  + pasture-based -They found that cows with an UHS of 4 had 1.5 times higher odds of developing clinical mastitis during the next month compared with cows with UHS of ≤2. Focused on **udder hygiene at the individual level with assessments on individual cows conducted once per month**
* **Fávero, S., Portilho, F.V.R., Oliveira, A.C.R., Langoni, H., Pantoja, J.C.F., 2015. Factors associated with mastitis epidemiologic indexes, animal hygiene, and bulk milk bacterial concentrations in dairy herds housed on compost bedding. Livestock Science 181, 220–230**
  + **This is very similar to both 10 40 herd study – modelling similar for 40 herd, look at table 3 to present descriptive stats example for 10 herds; important reference**
  + **CBP and milk quality**
  + **BTM culture:**
    - **Figure 5 has total bacteria count, coliforms and strep**
    - *“Bulk tank milk concentrations of total bacteria, coliforms, and streptococci were estimated by inoculating 100 mL of milk (undiluted to 104) onto Blood agar, McConkey, and Edward's medium, respectively. Plates were incubated at 37°C and read at 24 h. Results were expressed as log10 cfu/mL”*
    - Will be hard to pick out, then average, the BTM culture data for each of the three farms they studied (no supplemental)
  + The primary objective of this study was to identify compost bedding characteristics associated with mastitis epidemiologic indexes, cow cleanliness, and concentration of selected bacterial populations found in bulk tank milk. Secondary objectives were to monitor the occurrence of environmental mastitis outbreaks, and to describe the profile of pathogens isolated from mastitis cases of cows housed in the CBP system. Three dairies were **visited monthly during 1 year**. On each visit day, milk samples were collected from the bulk tank and from a sample of mammary quarters for microbiological examination. Milk samples were collected from all cases of clinical mastitis. Flank, leg, udder, and teat cleanliness were assessed using a score chart based on a 4-point scale (1 = clean to 4 = very dirty). Bedding samples were collected to estimate concentrations of total bacteria, streptococci, and coliforms, moisture, organic matter, carbon–nitrogen ratio, pH, and density. Mixed models were used to identify factors associated with incidence and prevalence of mastitis, and cow cleanliness.
  + Bedding moisture, carbon–nitrogen ratio, pH, and dry density were unconditionally associated with the incidence **of environmental clinical mastitis (selected cow quartermilk samples)**. Nonetheless, bedding moisture remained as a sole predictor in the final model
  + **The odds of a new case of subclinical mastitis, and of a cow having SCC > 200,000 cells/mL increased 32% and 16% for each one-unit increase in leg cleanliness score, respectively (saw link between hygiene score for leg and subclinical mastitis incidence and prevalence – curious not udder cleanliness score).** Overall means for udder, teat, flank, and leg hygiene scores were less than 2.1 for all farms and did not vary among seasons of the year. Bedding wet density was positively associated with all cleanliness scores and bulk milk concentration of total bacteria. Results suggest that managing bedding to remain dry and loose will result in cleaner animals with decreased risk of mastitis
  + n = 3 dairies: (1) bedded with peanut shells and tilled twice a day, (2) was bedded with sawdust and tilled twice a day, (3) bedded with sawdust and tilled twice a day
  + collected quartermilk samples from cows that were high on test (50% of high from smaller farms, 30% from bigger farm)
  + built models where outcome variables = mastitis epidemiologic indexes (incidence and prevalence of subclinical mastitis using DHIA) and cleanliness measures (udder, teat, flank, leg scores). Explanatory variables for mastitis vars included cleanliness measures, season, bedding characteristics. Explanatory vars for cleanliness scores included season, bedding age, bedding characteristics (pH, % dry matter, etc.) Used cutoff of p = 0.15 for preliminary univariate analysis
  + have estimates for **subclinical mastitis incidence and prevalence to compare to** (corresponds to “ANY IMI” and “NEW IMI” for me)
* **Albino, R. L., Taraba, J. L., Marcondes, M. I., Eckelkamp, E. A., & Bewley, J. M. (2018). Comparison of bacterial populations in bedding material, on teat ends, and in milk of cows housed in compost bedded pack barns. Animal Production Science, 58(9), 1686**
  + **CBP and milk quality (cow-level)**
    - **AVG SCC from DHIA 516,569 cells/mL**
  + **No data on BTM culture**
  + Looked at relationship of SCC and bacteria counts in composite milk samples, on teat skin, and udder/leg hygiene
    - n = 29 cows, 1 farm
    - Positive correlation between TBC and Strep count on teat end and teat hygiene score (p = 0.01)
    - Positive correlation between TBC on teat ends and SCC score (p = 0.03)
  + Concluded that positive associations between teat end hygiene and SCC/TBC were really just moderate, and hygiene score not an efficient tool to estimate bacterial populations on teat ends and in milk
    - indirect measures such as hygiene score do not provide reliable information for all type of bacteria concerning contamination on teat ends and milk
    - … because strep on teat ends associated with TBC of milk, and e coli on teat ends associated with colony count, but no association between hygiene score or SCC and e coli or colony count in milk
  + Used udder and leg scores 1-4 from Schreiner and Ruegg, scored on day 0 and 7; duplicate composite milk samples collected on day 0 and 7
* **Neja, W., Bogucki, M., Jankowska, M., Sawa, A., 2016. Effect of cow cleanliness in different housing systems on somatic cell count in milk. Acta Veterinaria Brno 85, 55–61**
  + **Not a great study to cite (only 2 farms, iffy design)**
  + The aim of the study was to analyze the effect of the housing system (tie-stall vs free-stall) on cow cleanliness; **only 1 farm in each category**
  + In the free-stall barn, there were over twice as many cows with clean udders (58%) and almost twice as few cows with very dirty udders; **but overall tie-stall cows had cleaner udders?**
  + Regardless of the housing system, the degree of udder dirtiness created differences (P ≤ 0.01) in the natural log somatic cell count; **no sig diff in LNSCC between the 2 farms**
  + highest quality milk (< 200 000 somatic cells/ml) was produced by clean cows (71.52%)
  + The proportion of cows with subclinical and clinical mastitis was found to increase with decreasing cleanliness of the udder, especially in the free-stall system.
  + Overall, the proportion of cows with clinical mastitis increased from 2.51% (clean cows) to 14.29% (dirty cows)

**Herd-level hygiene, herd-level SCC or IMI:**

* **Barkema, H. W., Y. H. Schukken, T. J. G. M. Lam, M. L. Beiboer, G.Benedictus, and A. Brand. 1998. Management practices associated with low, medium and high somatic cell counts in bulk milk. J.Dairy Sci. 81:1917–1927.**
  + “The environment and the cows themselves were cleaner for herds that produced milk with lower SCC values com-pared with herds with higher bulk tank SCC values”
  + “More attention to hygiene practices was found in herds with lower SCC”
  + Finds correlations between farms with good milk quality and the practices they use … “significant associations between management practices and BMSCC, those management practices were not necessarily causally related to BMSCC”
  + Percentage of cows with dirty udders, dirty thighs, and dirty anal regions was scored.
  + Cows were cleaner in herds with a low BMSCC, and the management practices for herds with low BMSCC more often included clipping the hair of all cows every year.
  + Observational
* **Cook, N. B. 2002. The influence of barn design on dairy cow hygiene, lameness, and udder health. Pages 97–103 in Proc. 35th Annu. Conv. Am. Assoc. Bov. Pract., Madison, WI. Frontier Printers Inc., Stillwater, OK.**
  + hygiene scoring is described which charts the distribution of manure over three areas of the body; udder, lower legs, and upper leg and flank.
  + *Patterns of hygiene differ for tiestall vs. freestall cows:* 
    - “Typically, freestall cows will have high lower leg scores due to poor alleyway hygiene. A few individual cows may have high flank and udder scores if they are lying in alleyways, but this does not usually present as a group problem”
    - “In contrast, tiestall cows usually have relatively clean lower legs, as they have less exposure to deep manure in alleys, but they tend to have higher flank and upper leg scores because of lying in manure deposited on the rear of the stall.”
  + **Positive association between NEW IMI rate and percent udders 3+4 on 20 Wisconsin dairies**

**Both herd-level and cow-level hygiene, AND herd-level SCC or IMI and cow-level SCC/IMI:**

* **Dohmen, W., Neijenhuis, F., Hogeveen, H., 2010. Relationship between udder health and hygiene on farms with an automatic milking system. Journal of Dairy Science 93, 4019–4033**
  + AMS farms
  + Herd-level findings:
    - The annual average herd SCC was positively related to the proportion of cows with dirty teats before milking and the proportion of cows with dirty thighs
    - The annual average percentage of new cows with a high SCC was positively related to the proportion of cows with dirty teats before milking and the proportion of milkings where teats were not covered with teat disinfecting spray by the AMS
  + Cow-level:
    - At the cow level, hygiene scores of the udder, thighs, and legs (range 1 to 4, where 1 is clean and 4 is very dirty) were related with cow SCC from the milk production test day closest to the farm visit using a general linear mixed model. The relationship between cow SCC and the hygiene score of the udder was positive
  + Very similar to my analysis, in that they did **univariate analysis on the relationship between the hygiene-specific variables and the udder health variables at farm level**
    - **dirty udder positively associated with avg herd annual SCC, annual avg percent new cows with high SCC, and annual incidence of clinical mastitis**
  + **multivariate analysis at FARM level = dirty teats related to avg herd annual SCC, annual avg percent new cows with high SCC, dirty thighs related to avg herd annual SCC** (dirty udders fell out of model)
  + **multivariate analysis at COW level = as udder hygiene score increased (got worse), cow-level SCC increased**
  + direct relationship was found between cow hygiene and SCC.
    - At farm level, the proportion of cows with dirty thighs and the proportion of cows with dirty teats before milking were positively related to annual average herd SCC
    - At cow level, the hygiene score of the udder was related to CSCC, with significant differences seen for the contrasts between scores 2 and 3 and between scores 2 and 4
* **Rowe, S., Tranter, W., Laven, R., 2021. Longitudinal study of herd udder hygiene and its association with clinical mastitis in pasture-based dairy cows. Journal of Dairy Science 104, 6051–6060**
  + The objectives of this exploratory study were to (1) describe the association between herd-level udder hygiene and clinical mastitis **in pasture-based systems**
  + the relationship between herd udder hygiene on each of 1, 2, and 3 d before each study day (d −1, −2, and −3, respectively) and clinical mastitis at the cow level on each study day (each in turn being set as d 0) was determined
  + **Herd udder hygiene** from d −1, −2, and −3 was positively associated with clinical mastitis on d 0 (incidence rate ratio = 1.4 per 10-point increase in the percentage of cows with poor udder hygiene)
  + we evaluated the effect of udder hygiene at the herd level estimated each day from assessments every 2 to 3 d on cow-level risk of clinical mastitis 1 to 3 d later

**Summary:**

Barkema 1998 – herd-level cleanliness, herd-level BTSCC – clipping hair of cows associated with being a low BTSCC

Cook – 2002 - herd-level cleanliness, herd-level new IMI rate - Positive association between NEW IMI rate and percent udders 3+4 on 20 Wisconsin dairies

Dohmen 2010 – both- **AMS** - Herd-level findings: dirty udder positively associated with avg herd annual SCC, annual avg percent new cows with high SCC, and annual incidence of clinical mastitis; dirty teats related to avg herd annual SCC, annual avg percent new cows with high SCC, dirty thighs related to avg herd annual SCC; cow level, the hygiene score of the udder was related to CSCC, with significant differences seen for the contrasts between scores 2 and 3 and between scores 2 and 4

Schreiner and Ruegg - Cow-level LS and hygiene, hygiene and both contagious and environmental IMI

Reneau - Significantly increased SCS as cow-level hygiene scores of udders and lower rear legs increased

Sant’Anna - very clean cows had the lowest SCLS, followed by the clean, dirty, and very dirty cows

De Pinho - Cow-level: There was a positive effect between the increase in UC score and the presence of IMI at the animal level

**hygiene of udder (legs?)**

**bedding material DEPTH**

* **Robles I, Kelton DF, Barkema HW, Keefe GP, Roy JP, von Keyserlingk MAG, DeVries TJ. Bacterial concentrations in bedding and their association with dairy cow hygiene and milk quality. Animal. 2020 May;14(5):1052-1066**
  + Objectives: if bedding type is associated with hygiene of cow body parts (lower legs, udder, upper legs, flank) AND housing and management factors associated with hygiene; also looked at farm avg SCC
  + 70 farms – 44 freestall, 26 tiestall; visited 3x one week apart
    - New sand (12), straw/dry forage (33), wood products (17), RMS (8)
      * Bedded packs = 2 and were excluded bc small sample size
    - Udder, lower legs and upper legs/flank were each scored on a 4-point hygiene scale (1 = very clean to 4 = very dirty) (Cook and Reinemann, 2007), and the percentage of cows with poor hygiene (scores 3 and 4) was calculated per farm and used for statistical analysis (Schreiner and Ruegg, 2003). Two trained researchers scored the cows, with each researcher scoring the same cows at each visit
    - High levels of agreement were found between the observers when scores, assessed independently, were categorized as good or poor hygiene (Cohen’s Kappa values for lower leg = 1.00; 95% CI = 1.00 to 1.00, udder = 0.79; 95% CI = 0.59 to 0.98, upper leg/ flank = 1.00; 95% CI = 1.00 to 1.00)
  + **Cows in freestall barns more often had dirty lower legs, upper legs and flanks compared to tie-stall barns (P < 0.001; Table 2)**
    - All three body hygiene scores (lower legs, udder, upper legs and flanks) were analysed in a separate multivariable analysis by housing, since housing type was associated (P < 0.001) with both the percentage of cows with dirty lower legs and with dirty upper legs and flanks (P < 0.001).
  + FREESTALL BARNS (table 3, n = 44 barns):
    - *Did explore if bedding material type had any effect; answer is no*
    - prop cows with dirty udders/upper legs increased with (1) decreased freq alleyway cleaning, (2) higher DIM for leg
    - **In FREESTALLS, farms with mattress-based stalls had a higher prevalence of cows with dirty upper legs/flanks compared to those using a deep bedding system (often inorganic sand) – p=0.10.**
  + TIESTALL BARNS (table 4, n = 26 barns):
    - *Didn’t have any predictor variables about bedding depth or stall base in tiestalls*
    - *Did explore if bedding material type had any effect; answer is no*
    - More dirty legs for cows with (1) access to pasture, (2) used lime
    - Farms adding bedding EOD more cows with dirty udders than farms adding bedding every day
  + *“The myriad of differences in both facility design and management practices between tie-stall barns and free-stall barns likely contributed to the differences in percentage point of cows with dirty upper legs and flanks between these two types of systems (Cook, 2002). However, system comparisons of this type are challenging and must be viewed with caution. Additionally, it is important to acknowledge that while these results provide insight in the scope discussed, interpretation must be viewed with caution due to a small sample size of farms, which was further limited once the analysis was completed by housing type. Results included yielded by these analyses do not necessarily include all factors influencing these outcome variables, thus relationships could vary given a larger sample size. Due to the relatively small sample size, there is potential for poor sensitivity, which may have hindered the detection of true associations, including curvilinear effects and interactions. The sample size required to test equivalence and non-inferiority would have been considerably large and not feasible for this particular research. Further, the potential for variation between herds in influencing the analysed outcomes and interactions should not be ignored”*
* **Wolfe, T., Vasseur, E., Devries, T.J., Bergeron, R., 2018. Effects of alternative deep bedding options on dairy cow preference, lying behavior, cleanliness, and teat end contamination. Journal of Dairy Science 101, 530–536.**
  + Had three treatments of freestall bedding: control (wheat straw) 2-3 cm, and deep switchgrass 14 cm, and deep switchgrass with lime 14 cm; compared hygiene between three treatments; 24 cows in a freestall setting, 8 cows in each treatment; each section had a treatment bedding
  + Scored 0-3 for cleanliness on day 13, 20, and 27; leg, flank, and udder
  + No treatment effects found for cow cleanliness score
  + **Deeper bedding didn’t keep cows cleaner than the control bedding**
  + [mentions differences in hygiene with difference in bedding *materials:* Fulwider 2007 = better leg and udder hygiene on mattresses or waterbeds vs. sand; Zdanowicz 2004 = cleaner udders on sawdust vs. sand; BUT van Gastelen et al., 2011 = no differences in cleanliness scores were found between cows housed on mattresses and various deep bedding materials, including sand; van Weyenberg et al., 2015 = no difference between deep-bedded straw-lime and Miscanthus (silvergrass)-lime]
* **de Vries, M., E. A. M. Bokkers, C. G. van Reenen, B. Engel, G. van Schaik, T. Dijkstra, and I. J. M. de Boer. 2015. Housing and management factors associated with indicators of dairy cattle welfare. Prev. Vet. Med. 118:80–92**
  + **deep-bedding (vs. mat/mattress) has been shown to reduce the likelihood of a cow having a dirty hindquarter by half**
  + observed hygiene of hindquarter on 179 farms in a freestall to identify housing and management factors associated with prevalence of different welfare indicators
    - divided up farms into groups based on bedding depth and lying surface:
      * Bedding height (cm)
        + <0.56 (52 farms)
        + 0.56–1.75 (54 farms)
        + >1.75 (60 farms)
        + **No association found here**
      * Predominant surface of lying area
        + Concrete (32 farms)
        + Hard mat (39 farms)
        + Soft mat/mattress (70 farms)
        + Deep bedding (33 farms)
  + Did univariate regression, used p values of 0.20!
  + presence of separate or continuous plaques of dirt amounting to at least the size of the palm of a hand was recorded for one hindquarter on a randomly chosen side of the body. These data were expressed at the herd level, as percentages of assessed cows with a dirty hindquarter
  + **prevalence of dirt hindquarters associated with surface of lying area; prevalence of dirty hindquarters negatively associated with deep bedding compared to hard mats**
* **Cook, N. B., J. P. Hess, M. R. Foy, T. B. Bennett, and R. L. Brotzman. 2016. Management characteristics, lameness, and body injuries of dairy cattle housed in high-performance dairy herds in Wisconsin. J. Dairy Sci. 99:5879–5891**
  + *“Use of deep, loose bedding yielded significant advantages over a mat or mattress type surface in terms of … proportion of cows with dirty udders (distinct demarcated to confluent plaques of manure)”*
  + **Deep bedding (vs. mat) decreases the prevalence of cows with dirty udders by 13% on high producing Wisconsin dairy farms using freestalls**
  + Udder hygiene was scored based on the system developed by Cook (2002) with 1 = clean with little or no evidence of manure, 2 = clean with only slight manure splashing, 3 = dirty with distinct demarcated plaques of manure, and 4 = filthy with confluent plaques of manure. Udder hygiene was reported as the proportion of cows scored with an udder score >2
  + Predictor was: “stall surface type: deep, loose surface (46 farms) VS. mat/mattress (20 farms)”
  + Of all 66 farms included (“high producing Wisconsin dairy farms”), % udders scored 3 and 4 was 12.1% +/- 14.8 SD
* **Fulwider, W. K., T. Grandin, D. J. Garrick, T. E. Engle, W. D. Lamm, N. L. Dalsted, and B. E. Rollin. 2007. Influence of free-stall base on tarsal joint lesions and hygiene in dairy cows. J. Dairy Sci.**

**90:3559–3566.**

* Cows on RFM and waterbeds had improved hygiene compared with cows on sand beds
* There was no difference in somatic cell count (SCC) by bed type (waterbed vs. sand vs. rubber-filled mattress)
* Hygiene of CBP similar to that of cows on waterbeds (too small n to actually compare statistically)
* Poor hygiene of the hind legs and udder was associated with increased SCS (don’t actually present raw data for this, just make the statement)

**mastitis (clinical? subclinical?)**

**bedding material DEPTH**

* **Preventing Mastitis Starts with Proper Management of Stall Bedding, University of Kentucky, Lilly Robinson and Donna M. Amaral-Phillips**
  + Tiestall/Mattresses: Depth of bedding needed has been established in deep-bedded freestalls, but less research has been done when using mattresses or water beds, as are commonly used in tiestalls. Depth of bedding is essential for comfort, but also essential for keeping moisture, and therefore bacteria, away from the udder. The recommendation is 1.5 lbs/cow/day (0.68 kg) for sawdust, and 2.5 lbs/cow/day for straw which will result in 1.4 inches of sawdust or 5 inches of straw bedding per stall. Consistently added and changed, this bedding could help prevent mastitis. The frequency that bedding is added also affects hock and knee lesions. Not changing bedding frequently enough, or not having adequate amounts of bedding, increases the incidence of lesions
* **Bickert, W. G., B. Holmes, K. A. Janni, D. Kammel, R. Stowell, and J. M. Zulovich. 2000. Dairy freestall housing and equipment. Pages 27–45 in Designing Facilities for the Milking Herd. 7th ed., Mid-West Plan Service, Iowa State University, Ames**
  + Recommended depth for bedding in freestalls is 15 cm (not sure how they got this…)
* **Designing and Building Dairy Cattle Freestalls, U Penn Extension, Dan McFarland and John Tyson**
  + Provide cushioning by a thick layer (6 to 8") of bedding on a firm base or by an intermediate layer, cushioning mat or mattress, and 1-2"of bedding
* **Mcpherson, S.E., Vasseur, E., 2020. Graduate Student Literature Review: The effects of bedding, stall length, and manger wall height on common outcome measures of dairy cow welfare in stall-based housing systems. Journal of Dairy Science 103, 10940–10950**
  + “Although there are no obvious bedding systems that result in cleaner cows, very little research has investigated the effect of bedding depth on cow cleanliness, and individual farmer management may play a significant role from farm to farm”

***Bedded packs and hygiene, bedded packs and milk quality*** *(BUT none of these actually study relationship between bedding depth, in a stall, more generally, and hygiene)*

* **Andrade, R.R., Tinôco, I.D.F.F., Damasceno, F.A., Ferraz, G.A.E.S., Freitas, L.C.D.S.R., Ferreira, C.D.F.S., Barbari, M., Baptista, F.D.J.F., Coelho, D.J.D.R., 2022. Spatial distribution of bed variables, animal welfare indicators, and milk production in a closed compost-bedded pack barn with a negative tunnel ventilation system. Journal of Thermal Biology 105, 103111**
  + Studied only 1 barn; random journal; not sure about this reference
  + **CBP and hygiene (herd-level)**
  + **No data on BTM culture (I don’t think, anyhow – can’t access full article – even if I could, this study is of questionable impact anyway)**
  + **Production data to compare to STD150 day milk?**
    - **the average milk production was 28.1 ± 7.2 kg day-1, and during summer, it was 26.9 ± 6.7 kg day**
  + “The high animal density significantly impacted the worsening of the bed moisture content and internal temperature. In general, dairy cows showed adequate hygiene (score of 1 and 2) and locomotion (score of 0 and 1) scores for the two climatic seasons evaluated, indicating good welfare conditions.”
  + Used Schreiner and Ruegg’s scoring scheme: “The udder and leg hygiene score was evaluated during milking, according to Schreiner and Ruegg (2002). A scale of 1–4 was used, with score of 1 corresponding to the absence of dirt in the regions evaluated, 2 indicating slightly dirty (2–10% dirt), 3 indicating moderately dirty (10–30% dirty), and 4 being filthy (more than 30% dirty)
  + Hygiene and locomotion scores were presented as percentages (%) and compared between the two climatic seasons (winter and summer). Non-parametric analysis was performed using the Wilcoxon test at the 5% level of significance. The scores are equivalent to assigned scores, considered ordinal qualitative variables, with do not have a normal distribution
  + 5.4% of animals 3 in summer, 4.9% 3 in winter (p = 0.09); none scored 4
* **Eckelkamp, E.A., Taraba, J.L., Akers, K.A., Harmon, R.J., Bewley, J.M., 2016. Sand bedded freestall and compost bedded pack effects on cow hygiene, locomotion, and mastitis indicators. Livestock Science 190, 48–57**
  + **CBP and milk quality (herd-level)**
    - **Has % ANY IMI to compare to (“high SCC prevalence” - percent of herd above 200k from DHIA)**
      * **The LSMeans (+/- SE) of** **HSP were 21.8 +/- 2.0 for CBP, 19.4 +/- 2.1% for sand-bedded freestalls**
      * **Lack of difference between HSP between well-managed CBPs and sand-bedded freestalls “is encouraging for producers considering CBP. The similarity indicates that CBP and SFB provide an environment for cattle that equally affects subclinical mastitis when good management is observed.”**
    - **Has DHI weighted avg SCC**
      * **“weighted average herd SCC (average of somatic cell count weighted by individual cow milk production; cells/mL”**
      * **Discrepancy between table 3, 1, and text** 
        + **251 +/- 75 (1000 cell/mL) (table 1) – raw mean**
        + **LSMeans (SE) DHI weighted average SCC of 241,716 +/-21,450 (table 3)**
  + **CBP and hygiene (herd-level)**
  + **No data on BTM culture (just herd-level DHIA stuff, cow-level clinical mastitis quartermilk samples)**
  + **Production data to compare to STD150 day milk?**
    - **test day milk production (kg/cow)**
    - **The DHI reported mean daily milk production over the year was 33.69 +/- 4.29**
  + Enrolled 8 compost barns, 7 sand freestalls which had maintained BTSCC below 300,000 cells/mL the year before (to ensure they were farms with “good management practices”)
  + Herds visited biweekly (26 times total) where 50 cows evaluated per herd for hygiene - The same observer scored hygiene at all visits on all farms; Hygiene evaluation of the lower legs, upper leg and flank, and udder was conducted using the 4-point system by Cook and Reinemann (2007) where: 1 = clean; 2 = moderate dirt; 3 = plaques of dirt with hair visible; 4 = confluent plaques of dirt with no hair visible
  + Created a herd mean hygiene for each herd at each visit period (?)
  + **No differences were observed between 8 CBP and 7 SFB for mean herd rear cow hygiene score** [LSMeans +/- SE for ~50 cows per herd per visit across 26 visits: hygiene score 2.19 +/- 0.05 for CBP, 2.26 +/- 0.06 for sand freestalls, p = 0.38]. “animals in both systems remained clean throughout the study.”
* **Eckelkamp, E.A., Taraba, J.L., Akers, K.A., Harmon, R.J., Bewley, J.M., 2016. Understanding compost bedded pack barns: Interactions among environmental factors, bedding characteristics, and udder health. Livestock Science 190, 35–42**
  + **CBP and milk quality (herd-level)**
    - **Don’t give any actual numbers for the high-SCC prevalence they had, just the models/conditional estimates and relationships**
    - **“Eckelkamp et al. (2016a) compared BTSCC CBP and sand-bedded FS and found no significant differences (229,582 vs. 205,131 cells/mL).” from Leso review – combed through actual paper and STILL cannot find this**
  + **Don’t see any production data to compare to STD150 day milk**
  + **CBP and hygiene (herd-level)**
  + **No data on BTM culture (just herd-level DHIA stuff, bacteria counts for bedding material)**
  + *Asked: what specific factors of the bedded pack influence hygiene and milk quality?*
  + Herd hygiene score decreased with increasing barn temp and increased with increasing compost moisture content. Herd SCC and high somatic cell prevalence both increased with increasing barn temp (hot weather = higher BTSCC bc of heat stress), but were unaffected by compost measurements. Cow hygiene and udder health indicators had a stronger relationship with barn temp than with CBP internal temperature and moisture. Herd hygiene score increased with increasing pack moisture content, and decreased with barn temp (cooler = messier cows)
  + Data was collected every 2-weeks (n=25 visits) from 8 Kentucky dairy farms with CBP from May 2013 to May 2014. A single observer scored 50 cows per farm for hygiene: Hygiene evaluation of the udder, lower leg, and upper leg and flank was conducted using the 4-point system of Cook and Reinemann (2007), where 1 = clean, 2 = moderate dirt, 3 = plaques of dirt with hair visible, and 4 = confluent plaques of dirt with no hair visible
* **Black, R.A., Taraba, J.L., Day, G.B., Damasceno, F.A., Bewley, J.M., 2013. Compost bedded pack dairy barn management, performance, and producer satisfaction. Journal of Dairy Science 96, 8060–8074**
  + **CBP and milk quality (herd-level)**
    - **SCC, cells/mL: 275,510 ± 20,080**
  + **CBP and hygiene (herd-level)**
  + **No data on BTM culture (just herd-level DHIA stuff)**
  + **Production data to compare to STD150 day milk (LS means – not sure what they are “controlling” for, vs. just reporting raw means)**
    - **30.7 ± 0.3 kg, daily milk production 13-24 months after moving into CBP barn**
    - **9,403 ± 74 Rolling herd average milk production, kg**
    - **Mature-equivalent 305-d milk production, kg; 10,599 ± 77**
    - **Average milk production per cow/d5 (L) 27.4 (25.3–30.4**
  + “reported a similar mean hygiene score of 2.2 +/- 0.7 (n=1699) for CBP in Kentucky” (can that n really be all cows he looked at? Accounted for clustering by farm?)
  + Looked at changes in monthly DHIA including milk production, SCC, reproductive performance, and daily bulk-tank somatic cell count after moving into the CBP
  + Bulk-tank somatic cell count decreased from the year before to the year after moving into the CBP barn (323,692 ± 7,301 vs. 252,859 ± 7,112 cells/mL, respectively) for farms using the CBP barn as the primary housing facility (n = 9); Daily milk production, collected from monthly Dairy Herd Improvement Association tests, increased from before moving into the CBP barn to the second year after (29.3 ± 0.3 vs. 30.7 ± 0.3 kg, respectively) for farms using the CBP barn as the primary housing facility (n = 8)
  + Herds selected must have maintained SCC under 300,000 previous year; facility type was only type used for lactating cows; all enrolled in DHI; all herds fed TMR; all herd mechanically ventilated barns; CBP were tilled 1-2x day and bedding added when moisture reached 55-60%
  + Each farm only visited once; only 34/47 were primary housing for cows; 12 or 15 farms of 42 included in SCC/DHIA analysis; hygiene scoring by "same observer at each farm visit"
* **Costa, J. H. C., T. A. Burnett, M. A. G. von Keyserlingk, and M. J. Hötzel. 2018. Prevalence of lameness and leg lesions of lactating dairy cows housed in southern Brazil: Effects of housing systems. J. Dairy Sci. 101:2395–2405**
  + The objectives of this study were to compare hygiene between 12 compost-bedded pack dairies (CB), 23 freestall dairies (FS), and 15 freestall dairies that used compost-bedded packs for vulnerable cows (FS+C)
  + Farm types did not differ in hygiene score: higher prevalence of dirty legs (5.0%) than udders (0.0%) and flanks (0.0%) in cows housed in CBP (defined as the prevalence of cows with a hygiene score ≥2 on a 3-point scale, where 1 = clean and 3 = soiled with large amounts of manure or dirt; Lombard et al., 2010).
  + **Hygiene better for barns using only CBP (but not statistically significant).** The prevalence of animals with dirtiness on all areas of the body was numerically higher in FS (2.1, 16.1, and 4.0% for udder, leg, and flank, respectively) and in FS dairies that used CBP only for vulnerable cows (2.1, 14.8, and 2.9% for udder, leg, and flank, respectively) than in CBP, but the differences were not statistically significant
  + **No data on BTM culture (just herd-level DHIA stuff)**
  + **Production data to compare to STD150 day milk**
    - **Average milk production per cow/d (L) 27.4 (25.3–30.4)**
    - **“Costa et al. (2018) reported lower milk production in CBP (27.4 L/cow per day) than in FS (31.3 L/cow per day)” but differences not statistically significant**
* **Shane, E.M., Endres, M.I., Janni, K.A., 2010. Alternative bedding materials for compost bedded pack barns in Minnesota: A descriptive study. Appl. Eng. Agric. 26, 465–473.** 
  + **CBP and hygiene (herd-level)**
  + **CBP and milk quality (herd-level)**
    - **425,000 cells/mL, across all 5 seasons, for 6 farms**
    - **Can’t tell if this is BTM, or avg cow-level SCC**
  + **BTM culture data!**
    - *“Bulk tank milk samples were collected from five consecutive bulk tank pickup days the week of our visit (samples were taken at the time milk was collected from the dairy by the processor after thorough mixing of the bulk tank milk) and frozen daily before being taken to the Laboratory for Udder Health, University of Minnesota and used for bacterial culture. Samples were collected during the winter and summer. For analysis, samples were thawed in a refrigerator. Once thawed, samples were thoroughly mixed, and 2 mL were removed from each sample and pooled into a sterile tube. After mixing, serial 10‐fold dilutions were made in sterile brain heart infusion broth. Two hundred microliters from each dilution were spread over the surface of separate MacConkey agar, TKT agar, and Factor agar plates. After 24 h of incubation at 37°C, the plates having 30 to 300 colonies were chosen for enumeration of bacteria. Those colonies that appeared to be Staphylococcus aureus were presumptively identified by catalase activity, tube coagulase test, and biochemical reactions using the API‐STAPH (BioMerieux, Hazelwood, Mo.). Bacterial counts are recorded as number of bacteria per mL of bulk tank milk”*
    - Table 6, shows pooled results for multiple visits for each of 6 farms, one pooled result for summer and one for winter; has coliforms, env. strep, SA, staph spp.
  + **Production data to compare to STD150 day milk**
    - **33 kg/day milk production from DHIA (across all seasons… is this cow-level? Has to be cow-level…)**
  + Collected bulk tank milk (bacteriology and SCC), hygiene scores from n = 6 farms, each visited 4 times over a year; scored 1-5 hygiene (Reneau et al., 2005)
  + “reported mean herd hygiene score of 3.1 for all cows housed in CBP using several different bedding materials” … but this is on a 5-point scale
  + Report SCC but don’t compare to other systems
* **Barberg, A.E., Endres, M.I., Salfer, J.A., Reneau, J.K., 2007b. Performance and welfare of dairy cows in an alternative housing system in Minnesota. J. Dairy Sci. 90(3), 1575–1583.**
  + **CBP and hygiene (herd-level)**
  + **CBP and milk quality (herd-level)**
    - **Seems to use DHIA SCC as avg cow-level SCC, and BTSCC is something different**
      * **Dairy Herd Improvement Association somatic cell count (SCC) was 325,000 ± 172,000 cells/mL**
      * **“The DHIA SCC was 325,000 ± 172,000 cells/mL. The BTSCC for the month prior to our visit was 261,000 ± 98,000 cells/mL”**
    - **“mastitis rates: herd mastitis infection rates were calculated as a percentage of infected cows in the lactating herd” --- anyIMI for my study**
      * **overall mastitis infection rate was … 27.7% after cows were moved to the compost dairy barn for 12 farms. The Minnesota 2005 DHIA average percentage of cows infected in herds was 32**
  + **Production data to compare to STD150 day milk**
    - **Rolling herd average was 10,457 ± 1,138 kg per cow**
  + **BTM culture data!**
    - Methodology exactly as Shane 2010
    - Don’t actually have any raw data (table, figure, etc.) in publication…
    - *“In general, a low level of contagious pathogens was detected in the milk bulk tank samples. One out of 12 farms had a high level of Streptococcus agalactiae, 1 farm had a high level of Staphylococcus aureus, 6 farms had high levels of non-agalactiae streptococci, and 5 farms had high levels of coliforms (i.e., Escherichia coli, Klebsiella, and Enterobacter) in the milk. Mycoplasma was not isolated from any of the bulk tank milk samples. There was no association between high BTSCC and level of contagious pathogens in the herd, contrary to what has been found in other studies (Elbers et al., 1998; Rodrigues et al., 2005). It is possible that herds in the current study were discarding milk from chronically infected cows; therefore, the association was not found. More research is needed in this area.”*
  + Describe the housing system, identify management practices, observe cow welfare, analyze herd performance and udder health prior to and following switch to CBP
  + Collected BTM, hygiene scores, DHIA SCC average for all farms at time of visit; total bacteria count; bulk tank cultures; total bacteria count in bedding; BTSCC before and after CBP; herd mastitis rates from DHIA
  + SCC at time of visit was 325,000±172,000 cells/mL, hygiene score was 2.66±0.19. Historical analysis of the bulk tank SCC showed that 3 out of the 7 herds analyzed had a significant reduction in bulk tank SCC when compared with the previous housing system. Mastitis infection rates decreased significantly by 12% on 6 of the 9 farms analyzed.
  + Herd mastitis infection rates were calculated from the DHIA records for 2 yr prior to housing in CBP and at least 1 yr after housing the cows on CBP. A cow was considered infected when SCC≥200,000 cells/mL on a DHIA test (my “ANY IMI”). Herd mastitis infection rates were calculated as a percentage of infected cows in the lactating herd
  + Mean hygiene score 2.7 +/- 0.2 for cows housed in CBP in Minnesota
  + The average DHIA SCC for the test date nearest to each farm visit was 325,000 ± 172,000 cells/mL (range of 88,000 to 658,000 cells/mL). The state average SCC for Minnesota herds enrolled in the DHIA was 357,000 cells/mL for Holsteins in 2005, slightly greater than herds in the current study.
    - **BTSCC comparable/slightly better than Minnesota state average**
  + The overall mastitis infection rate was 35.4% prior to moving cows to a compost barn and 27.7% after cows were moved to the compost dairy barn. The 2005 DHIA average percentage of cows infected in herds was 32
    - **“Mastitis rate” of bedded pack farms comparable/slightly better than Minnesota state average**
* **Lobeck, K.M., Endres, M.I., Shane, E.M., Godden, S.M., Fetrow, J., 2011. Animal welfare in cross-ventilated, compost-bedded pack, and naturally ventilated dairy barns in the upper Midwest. Journal of Dairy Science 94, 5469–5479.**
  + **CBP and hygiene (herd-level)**
  + **CBP and milk quality (herd-level)**
    - **“mastitis prevalence: herd mastitis infection rates were calculated as a percentage of infected cows in the lactating herd” --- anyIMI for my study**
      * **“Mastitis infection prevalence was calculated by the number of animals with a test SCC >200,000 cells/mL divided by the total number of animals in the pen. The test date nearest to the farm visit was used for analysis”**
      * **Mastitis infection prevalence was 33.4, 26.8, and 26.8% for CB, CV, and NV barns, respectively, with no differences in prevalence among housing systems. No adjustment factors were significant in the model.**
    - **DHIA SCC: so, avg cow-level SCC?**
      * **434,000 cells/mL +/- SD 1,197 for 6 bedded packs in Upper Midwest**
  + **No data on BTM culture (just DHIA stuff – “mastitis infection prevalence” – proportion animals over 200k on a test day, exact same as my “any IMI”)**
  + **Production data to compare to STD150 day milk**
    - **Milk production for the 15 herds on DHIA was 34.7 kg of FCM/cow per day for 6 CB barns**
    - **Estimated 305ME production was 11,154 kg for 6 CB barns;**
    - **Direct comparison of different housing systems: “Lobeck et al. (2011) found similar 305-d mature equivalent milk production in CBP (11,154 kg), cross-ventilated FS (11,536 kg), and naturally ventilated FS (11,236 kg)” from Leso review**
  + Investigate animal welfare in cross-ventilated freestall barns (CV) and compost-bedded-pack barns (CB), compared with conventional, naturally ventilated freestall barns (NV), Outcome-based measurements of welfare (hygiene, mastitis prevalence) were collected on each farm.
  + 18 barns total, 6 compost BP; herds visited 4 times each
  + **“mastitis prevalence did not differ among housing systems”**
    - Mastitis infection prevalence was calculated by the number of animals with a test SCC >200,000 cells/mL divided by the total number of animals in the pen (my “% ANY IMI”). The test date nearest to the farm visit was used for analysis
    - mastitis infection prevalence was 33.4, 26.8, and 26.8% for CB, CV, and NV barns, respectively, with no differences in prevalence among housing systems. No adjustment factors were significant in the model
  + Animals in CBP exhibited higher overall hygiene score than cross-ventilated and naturally ventilated sand freestall barns (3.18, 2.83, 2.77; p = 0.02 and 0.01)
    - Hygiene scores (1 to 5 scale, where 1 = clean and 5 = very dirty; udder and lower hind legs, Reneau et al., 2005) were higher for CB (3.18) than CV (2.83) and NV (2.77) barns, with no differences between CV and NV barns.
    - Attribute difference especially to winter hygiene scores when broke it down into season (winter scores analyzed separately were higher with statistical significance; moisture content of CBP increases over cooler months of the year, increased moisture content allows more material to adhere more easily to animals, increasing hygiene score
    - Producers report difficulty keeping CBP at optimal moisture and temperature in winter
* **Heins, B.J., Sjostrom, L.S., Endres, M.I., Carillo, M.R., King, R., Moon, R.D., Sorge, U.S., 2019. Effects of winter housing systems on production, economics, body weight, body condition score, and bedding cultures for organic dairy cows. Journal of Dairy Science 102, 706–714**
  + **CBP and milk quality (cow-level)** 
    - **(Least squares means) SCS 2.57 +/- SEM 0.1 for indoor compost bedded pack, year-round avg for 3 years of WINTER data**
  + **Production data to compare to STD150 day milk**
    - **(Least squares means) Milk kg/d 15.8 +/- 0.4 SEM for indoor compost bedded pack for 3 winters; energy-corrected = 15.7 kg/d, fat-corrected = 15.9 kg/d**
  + **No data on BTM culture (just DHIA stuff – “**Milk, fat, and protein production and SCS were recorded from monthly milk recording”)
  + Organic dairy cows were used to evaluate the effect of 2 winter housing systems on milk production, **somatic cell score**, body weight, BCS, and economics across 3 winter seasons. Outdoor straw pack VS. indoor 3-sided compost bedded pack barn (wood chips and shavings).
  + SCS were recorded from monthly milk recording; For statistical analysis of individual cow SCS, independent variables were effects of breed, parity (1, 2, or 3+), year of study, housing system, the interaction of housing system and year of study, along with replicated housing system within year of study and cow within housing system and year of study as a random effect
  + 2 replicates within each treatment, n = 140 cows in outdoor straw, n = 128 in CBP
  + SCS, were not different for the outdoor (2.64, SEM 0.1) and indoor housing systems (2.57, SEM 0.1)
* **Lobeck, K. M., M. I. Endres, K. A. Janni, S. M. Godden, and J. Fetrow. 2012. Environmental characteristics and bacterial counts in bedding and milk bulk tank of low profile cross-ventilated, naturally ventilated, and compost bedded pack dairy barns. Appl. Eng. Agric. 28:117–128**
  + Compared milk bacterial counts in CBP, naturally ventilated FS, and low-profile cross-ventilated FS and found no differences among the housing systems.
  + **NO production data to compare to STD150 day milk**
  + **BTM culture data!**
    - Methodology exactly as Shane 2010 *(“Milk bulk tank samples were collected during winter and summer from five consecutive bulk tank pickups by the milk plant personnel at each dairy”)*
    - Comprehensive culture results shown in table 12; coliforms, non-ag strep, staph spp., SA
    - Compares CBP, cross-ventilated and naturally-ventilated freestall barns
* **Fulwider, W. K., T. Grandin, D. J. Garrick, T. E. Engle, W. D. Lamm, N. L. Dalsted, and B. E. Rollin. 2007. Influence of free-stall base on tarsal joint lesions and hygiene in dairy cows. J. Dairy Sci.**

**90:3559–3566.**

* + **CBP and milk quality (cow-level)**
    - **AVG SCC from DHIA 176,700 cells/mL**
* **Leso, L., M. Uberti, W. Morshed, and M. Barbari. 2013. A survey of Italian compost dairy barns. J. Agric. Eng. XLIV(e17):120–124**
  + **CBP and milk quality (cow-level)**
    - **AVG SCC from DHIA 354,000 cells/mL**
  + **Production data to compare to STD150 day milk**
    - **Milk yield (kg/cow\*day) mean 30.8, SD (3.05); 10 farms using CBP in Italy**
* **Fávero, S., Portilho, F.V.R., Oliveira, A.C.R., Langoni, H., Pantoja, J.C.F., 2015. Factors associated with mastitis epidemiologic indexes, animal hygiene, and bulk milk bacterial concentrations in dairy herds housed on compost bedding. Livestock Science 181, 220–230**
  + have estimates for **subclinical mastitis incidence and prevalence to compare to** (corresponds to “ANY IMI” and “NEW IMI” for me)
  + “mastitis risk is affected by bedded pack conditions and cow hygiene level. The odds of a case of environmental clinical mastitis increased 5.7% for each 1-unit increase in bedding moisture, whereas the mastitis infection prevalence increased 16% for each 1-unit increase in leg cleanliness score (on a 4-point scale)”
  + **This is very similar to both 10 40 herd study – modelling similar for 40 herd, look at table 3 to present descriptive stats example for 10 herds; important reference**
  + **CBP and milk quality**
  + **The odds of a new case of subclinical mastitis, and of a cow having SCC > 200,000 cells/mL increased 32% and 16% for each one-unit increase in leg cleanliness score, respectively (saw link between hygiene score for leg and subclinical mastitis incidence and prevalence – curious not udder cleanliness score).** Overall means for udder, teat, flank, and leg hygiene scores were less than 2.1 for all farms and did not vary among seasons of the year. Bedding wet density was positively associated with all cleanliness scores and bulk milk concentration of total bacteria. Results suggest that managing bedding to remain dry and loose will result in cleaner animals with decreased risk of mastitis
  + have estimates for **subclinical mastitis incidence and prevalence to compare to** (corresponds to “ANY IMI” and “NEW IMI” for me)
  + **BTM coliforms**
    - **2.8 CFU/mL avg for CBP three farms (each with multiple visits)**
  + **% ANY IMI**
    - **43.8% avg for three CBP farms**
  + **% NEW IMI**
    - **20.9% avg for three CBP farms**
  + **NO production data to compare to STD150 day milk**
* **Albino, R. L., Taraba, J. L., Marcondes, M. I., Eckelkamp, E. A., & Bewley, J. M. (2018). Comparison of bacterial populations in bedding material, on teat ends, and in milk of cows housed in compost bedded pack barns. Animal Production Science, 58(9), 1686**
  + **CBP and milk quality (cow-level)**
    - **AVG SCC from DHIA 516,569 cells/mL**
  + **Production data to compare to STD150 day milk**
    - **The experiment was conducted on a commercial dairy farm in Kentucky housing 128 Holstein cows in a CBP, the mean milk production per cow was 35 kg/day.**
* **Black, R. A., J. L. Taraba, G. B. Day, F. A. Damasceno, M. C. Newman, K. A. Akers, C. L. Wood, K. J. McQuerry, and J. M. Bewley. 2014. The relationship between compost bedded pack performance, management, and bacterial counts. J. Dairy Sci. 97(5):2669-4272679.**
  + No hygiene content
  + **CBP and milk quality (cow-level)**
    - **AVG SCC from DHIA 246,500 cells/mL**
  + **Production data to compare to STD150 day milk**
    - **During winter - Producers subjectively reported a daily milk production and SCC of 27.3 ± 4.0 kg (n = 39) for farms in Kentucky**
* **Leso, L., Barbari, M., Lopes, M.A., Damasceno, F.A., Galama, P., Taraba, J.L., Kuipers, A., 2020. Invited review: Compost-bedded pack barns for dairy cows. Journal of Dairy Science 103, 1072–1099**
  + “In the studies included in this section, SCC is expressed as the average SCC of all cows measured by the DHI service during monthly herd checks. The prevalence of mastitis infection is defined as the proportion of cows with SCC >200,000 cells/mL on the day the data were obtained”
  + “Milk production and quality in CBP have been measured in several studies. In dairy operations, milk yield can be affected by several factors; therefore, quantifying the effect of housing system alone is challenging. The results in the literature indicate that high levels of milk production are possible in CBP. Furthermore, because CBP has the potential to improve cow comfort, greater milk production than that in other housing systems such as FS might be expected. However, a comparison of milk yield of cows housed in CBP and FS did not show a clear difference.”
  + Summary from Lesso review sums it up pretty well:
    - Studies regarding the hygiene of cows in CBP have shown inconsistent results, and both the hygiene scores and prevalence of dirty cows vary widely (Table 2). Compared with cows housed in FS, cows housed in CBP have comparable or poorer hygiene levels. Most authors have highlighted that the hygiene of cows in CBP depends on the conditions of the bedded pack, and pack moisture is the most important parameter. Generally, increased pack moisture results in higher hygiene scores because wet materials adhere more easily to animals (Black et al., 2013; Eckelkamp et al., 2016b). In temperate climates, cows in CBP tend to be dirtier during winter because maintaining adequately dry bedding in cold and humid weather can be challenging (Lobeck et al., 2011). In some studies, high pack temperatures have been associated with cleaner animals. The results emphasize the importance of proper pack management in CBP.
  + ***Depends on how you manage the pack, and ambient weather conditions!***

**Summary:**

Favero 2015 – describes BP milk quality, no comparison - studied 3 BPs – took BT sample 1x month for 12 months, looked at clinical mastitis cases and also records analysis so has % new, % any

Albino 2018 -– describes BP milk quality, no comparison - cow-level, describes type of bacteria present in quartermilk

Eckelcamp 2016 “Understanding…” -– describes BP milk quality, no comparison - looked at weighted avg SCC, prod. Reported clinical mastitis incidence, and high SCC prev

Black 2013 - describes BP milk quality, no (direct) comparison - Looked at changes in monthly DHIA including SCC, daily bulk-tank somatic cell count after moving into the CBP for individual herds; compares to Kentucky DHIA, says CBPs lower than Kentucky avg

Barberg 2007b - describes BP milk quality, no (direct) comparison – looked at BPs before and after for same farms, how avg DHIA SCC changed; compares farms to themselves before and after than to all Minnesota farms using DHIA – CBPs slightly better than state avg that year

Heins 2019 - describes BP milk quality, no comparison – study compares straw pack to CBP

Eckelcamp 2016 “Sand bedded…” – direct comparison of BPs to sand FS – compared mastitis indicators (herd clinical mastitis, herd SCC, high SCC prevalence, BTSCC) – table 3 - no differences observed; then also compared herd mean SCC to rest of Kentucky – sand FS below state avg for that year, BPs slightly above

Lobeck 2011- describes BP milk quality, direct comparison to two types of sand freestall – describes mastitis prevalence

**Why see these associations between dairy cow hygiene and SCC in milk?**

* Reduced exposure of clean animals to environmental pathogens
* Effect of poor cow hygiene with a lower efficiency for pre- and post-dipping, which could result in an increase in incidence of contagious mastitis

**Dearth of studies on bedding depth (in stall) and hygiene? Bedding depth (in stall) and mastitis risk?**

* Why? People have looked at lying times, leg injuries and lesions; also cite lying time increases with deeper bedding in sand-bedded free stalls (Drissler 2005)
* **Tucker, C.B., Weary, D.M., Von Keyserlingk, M.A.G., Beauchemin, K.A., 2009. Cow comfort in tie-stalls: Increased depth of shavings or straw bedding increases lying time. Journal of Dairy Science 92, 2684–2690**
  + Looked at lying time in tiestalls and bedding depth but not effect on hygiene or mastitis risk; cows lied down more as both shavings and straw got deeper
* **Alanis VM, Zurakowski M, Pawloski D, Tomazi T, Nydam DV, Ospina PA. Description of the Characteristics of Five Bedding Materials and Association with Bulk Tank Milk Quality on Five New York Dairy Herds. Front Vet Sci. 2021 Apr 30;8:636833**
  + **Probably will be helpful for 10 herd? In 40 herd, comparing facility type, not bedding material really**
  + No association between bulk tank somatic cell counts based on bedding type were observed. Despite using an SOP for bedding sampling in an effort to consistently collect samples, we still observed a large amount of variability both within and among bedding samples. This variability may have obscured any potential association between BT milk quality and bedding type.
* **Freu, G.; Garcia, B.L.N.; Tomazi, T.; Di Leo, G.S.; Gheller, L.S.; Bronzo, V.; Moroni, P.; Dos Santos, M.V. Association between Mastitis Occurrence in Dairy Cows and Bedding Characteristics of Compost-Bedded Pack Barns. Pathogens 2023, 12, 583**
  + **Cow-level pathogen descriptions, not helpful right now for 40 herd but will be for 10 herd**
  + this study characterized the frequency and profile of pathogens isolated from clinical (CM) and subclinical (SCM) mastitis in dairy cows housed in CB
  + Our results showed that Escherichia coli and environmental streptococci were the most frequently isolated pathogens from CM cases, while Staphylococcus chromogenes and contagious pathogens (Staphylococcus aureus and Streptococcus agalactiae) were the most commonly isolated from SCM cases. Bedding moisture content was positively associated with the incidence of CM. The bedding carbon to nitrogen ratio was negatively associated with the incidence of SCM, and the bedding total bacteria counts tended to be associated with the incidence of SCM. Bedding counts of coliforms positively associated with the prevalence of SCM. Our results can support decision-makers in the dairy industry seeking strategies for bedding management and mastitis control.
* **Cook, N. B., T. B. Bennett, and K. V. Nordlund. 2005. Monitoring indices of cow comfort in free-stall-housed dairy herds. J. Dairy Sci. 88:3876–3885.**
* **Hogan, J., and K. L. Smith. 2012. Managing environmental mastitis. Vet. Clin. North Am. Food Anim. Pract. 28:217–224**
* **Tucker, C. B., and D. M. Weary. 2004. Bedding on geotextile mattresses: How much is needed to improve cow comfort? J. Dairy Sci. 87:2889–2895**
* **Barkema, H.W., M.A.G. von Keyserlingk, J.P. Kastelic, T.J.G.M. Lam, C. Luby, J.-P. Roy, S.J. LeBlanc, G.P. Keefe, and D.F. Kelton. 2015. Invited review: Changes in the dairy industry affecting dairy cattle health and welfare. Journal of Dairy Science 98:11 7426-7445.**
* **Klaas IC, Zadoks RN. An update on environmental mastitis: Challenging perceptions. Transbound Emerg Dis. 2018 May;65 Suppl 1:166-185.**
* **Bewley, J., J. Taraba, G. Day, R. Black, and F. Damasceno. 2012. University of Kentucky Cooperative Extension. Compost Bedded Pack Barn Design: Features and Management Consideration**

***Just production notes***

* **Eckelkamp, E.A., Taraba, J.L., Akers, K.A., Harmon, R.J., Bewley, J.M., 2016. Sand bedded freestall and compost bedded pack effects on cow hygiene, locomotion, and mastitis indicators. Livestock Science 190, 48–57**
  + *\*\*\* comparison between facility types\*\*\**
  + **Production data to compare to STD150 day milk?**
    - **test day milk production (kg/cow)**
    - **The DHI reported** **mean daily milk production over the year was 33.69 +/- 4.29 for CBP; 32.15 +/- 4.83 kg/cow/day for SFB**
* **Lobeck, K.M., Endres, M.I., Shane, E.M., Godden, S.M., Fetrow, J., 2011. Animal welfare in cross-ventilated, compost-bedded pack, and naturally ventilated dairy barns in the upper Midwest. Journal of Dairy Science 94, 5469–5479.**
  + *\*\*\* comparison between facility types\*\*\**
  + **Production data to compare to STD150 day milk**
    - **Milk production for the 15 herds on DHIA was 34.7 kg of FCM/cow per day for 6 CB barns**
    - **Estimated 305ME production was 11,154 kg for 6 CB barns;**
    - **Direct comparison of different housing systems: “Lobeck et al. (2011) found** **similar 305-d mature equivalent milk production in CBP (11,154 kg), cross-ventilated FS (11,536 kg), and naturally ventilated FS (11,236 kg)” from Leso review**
* **Costa, J. H. C., T. A. Burnett, M. A. G. von Keyserlingk, and M. J. Hötzel. 2018. Prevalence of lameness and leg lesions of lactating dairy cows housed in southern Brazil: Effects of housing systems. J. Dairy Sci. 101:2395–2405**
  + *\*\*\* comparison between facility types\*\*\**
  + The objectives of this study were to compare hygiene between 12 compost-bedded pack dairies (CB), 23 freestall dairies (FS), and 15 freestall dairies that used compost-bedded packs for vulnerable cows (FS+C)
  + **Production data to compare to STD150 day milk**
    - **Average milk production per cow/d (L) 27.4 (25.3–30.4)**
    - **“Costa et al. (2018) reported lower milk production in CBP (27.4 L/cow per day) than in FS (31.3 L/cow per day)” but differences not statistically significant**
* **Andrade, R.R., Tinôco, I.D.F.F., Damasceno, F.A., Ferraz, G.A.E.S., Freitas, L.C.D.S.R., Ferreira, C.D.F.S., Barbari, M., Baptista, F.D.J.F., Coelho, D.J.D.R., 2022. Spatial distribution of bed variables, animal welfare indicators, and milk production in a closed compost-bedded pack barn with a negative tunnel ventilation system. Journal of Thermal Biology 105, 103111**
  + Studied only 1 barn; random journal; not sure about this reference
  + **Production data to compare to STD150 day milk?**
    - **the average milk production was 28.1 ± 7.2 kg day-1, and during summer, it was 26.9 ± 6.7 kg day**
* **Black, R.A., Taraba, J.L., Day, G.B., Damasceno, F.A., Bewley, J.M., 2013. Compost bedded pack dairy barn management, performance, and producer satisfaction. Journal of Dairy Science 96, 8060–8074**
  + **Production data to compare to STD150 day milk (LS means – not sure what they are “controlling” for, vs. just reporting raw means)**
    - **30.7 ± 0.3 kg, daily milk production 13-24 months after moving into CBP barn**
    - **9,403 ± 74 Rolling herd average milk production, kg**
    - **Mature-equivalent 305-d milk production, kg; 10,599 ± 77**
    - **Average milk production per cow/d5 (L) 27.4 (25.3–30.4**
* **Shane, E.M., Endres, M.I., Janni, K.A., 2010. Alternative bedding materials for compost bedded pack barns in Minnesota: A descriptive study. Appl. Eng. Agric. 26, 465–473.** 
  + **Production data to compare to STD150 day milk**
    - **33 kg/day milk production from DHIA (across all seasons… is this cow-level? Has to be cow-level…)**
* **Barberg, A.E., Endres, M.I., Salfer, J.A., Reneau, J.K., 2007b. Performance and welfare of dairy cows in an alternative housing system in Minnesota. J. Dairy Sci. 90(3), 1575–1583.**
  + **Production data to compare to STD150 day milk**
    - **Rolling herd average was 10,457 ± 1,138 kg per cow**
* **Heins, B.J., Sjostrom, L.S., Endres, M.I., Carillo, M.R., King, R., Moon, R.D., Sorge, U.S., 2019. Effects of winter housing systems on production, economics, body weight, body condition score, and bedding cultures for organic dairy cows. Journal of Dairy Science 102, 706–714**
  + **Production data to compare to STD150 day milk**
    - **(Least squares means) Milk kg/d 15.8 +/- 0.4 SEM for indoor compost bedded pack for 3 winters; energy-corrected = 15.7 kg/d, fat-corrected = 15.9 kg/d**
* **Leso, L., M. Uberti, W. Morshed, and M. Barbari. 2013. A survey of Italian compost dairy barns. J. Agric. Eng. XLIV(e17):120–124**
  + **Production data to compare to STD150 day milk**
    - **Milk yield (kg/cow\*day) mean 30.8, SD (3.05); 10 farms using CBP in Italy**
* **Albino, R. L., Taraba, J. L., Marcondes, M. I., Eckelkamp, E. A., & Bewley, J. M. (2018). Comparison of bacterial populations in bedding material, on teat ends, and in milk of cows housed in compost bedded pack barns. Animal Production Science, 58(9), 1686**
  + **Production data to compare to STD150 day milk**
    - **The experiment was conducted on a commercial dairy farm in Kentucky housing 128 Holstein cows in a CBP, the mean milk production per cow was 35 kg/day.**
* **Black, R. A., J. L. Taraba, G. B. Day, F. A. Damasceno, M. C. Newman, K. A. Akers, C. L. Wood, K. J. McQuerry, and J. M. Bewley. 2014. The relationship between compost bedded pack performance, management, and bacterial counts. J. Dairy Sci. 97(5):2669-4272679.**
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