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Environmental enrichment for goats: a scoping review protocol

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TITLE

Environmental enrichment for goats: a scoping review protocol

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Author contributions:

JT: study conceptualization; literature search lead; training of additional reviewers; study selection/screening, data extraction, data formatting for results and discussion lead; final manuscript lead

CM: study conceptualization; content and methodology expertise; final manuscript development

Additional reviewers (undergraduate research assistants): participation in study selection/screening and data extraction

Keywords

Capra hircus; housing; rearing environment; animal welfare; animal management

Registration

This protocol was submitted online to SYREAF (<https://syreaf.org/>) and eScholarship, University of California, Davis (<https://escholarship.org/>), on 9 September 2024.

Amendments

Any amendments to this protocol will be rationalized and dated.

INTRODUCTION

Rationale

Domestic goats under human care are kept for production of milk, meat, fiber, and hide; for provision of services like land management and packing; and for research/teaching purposes (USDA–APHIS–VS–CEAH–NAHMS, 2019; NFACC, 2020). The global population of goats has now surpassed one billion head (FAO, 2021), with goats being kept in a wide variety of agro-ecological zones on small- and large-scale farming systems (Pandey and Upadhyay, 2022). In countries with high production per animal (e.g., the U.S., Europe), it is likely that operations will continue to increase production, while countries with lower production will move towards intensification of housing and management (Zobel et al., 2019). Methods such as confinement allow for certain benefits (e.g., closer monitoring; protection from predators; and reduced exposure to parasites, infectious disease agents, and the elements), but typically at the cost of limiting mental stimulation, what behaviors animals can perform, and who they interact with (Zobel et al., 2019; Zobel and Nawroth, 2020). In other words, goat welfare in terms of aspects of biological functioning, affective state, and natural living (Fraser et al., 1997) may be negatively affected.

One way to improve the welfare of captive animals is through environmental enrichment, which involves modifications to the environment that improve an animal's physical health, psychological state, or allows for expression of behaviors characteristic to the species (Bloomsith, 1991; Newberry, 1995; Mandel et al., 2016). Enriched environments during early life are known to be important for development (e.g., piglets, behavioral and social: Vanheukelom et al., 2012; laying chicks and pullets, behavioral and physiological: Campbell et al., 2019). Environmental enrichment for goats may be particularly important due to their evolutionary cognitive capacities which allow them to navigate complex physical and social environments and for deterring "mischievous" (i.e., unwanted) behaviors directed towards their housing, with provision to kids proposed for enabling safe interactions with enrichment later in life (Zobel and Nawroth, 2020).

Industry experts have previously reviewed environmental enrichment concerning goats (NFACC, 2020; Botreau et al., 2023a; Botreau et al., 2023b; Ginane and Rørvang, 2023; de Oliveira and Boivin, 2024), however without use of a systematic approach. Therefore, we aim to conduct a scoping review to gather scientific publications using the following structured search strategies of the peer-reviewed literature regarding this topic.

Objectives

The overall objectives of this scoping review are to a) describe environmental enrichment items or experiences that have been assessed for all ages of domesticated goats globally, and b) describe how these items or experiences have been quantified and when they were measured.

METHODS

Protocol

The present review will follow the procedures for the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist (Tricco et al., 2018).

Eligibility criteria

Publication type: Included studies will be those published 1960-present, with no limit to country/location of publication. The year 1960 was chosen to reflect the global rise in animal welfare-related legislation and research. Included studies may be analytical experimental or observational (cross-sectional, cohort, case-control, or hybrid) designs, involving data from direct observation or from pre-existing sources/databases. Only peer-reviewed studies written in English will be included. The following will be excluded: literature published before 1960, descriptive or review papers, grey literature (e.g., conference proceedings, theses and dissertations), studies not written in English, and studies from journals that do not have a peer-review process for publication.

Population: The population of focus is domesticated goat breeds under human care raised for the purpose of production of milk, meat, fiber, or hide; for provision of services like land management or packing; or for research/teaching. Studies will be excluded if they utilize wild goats, feral goats, goats in zoos/petting zoos, or those not raised for the purpose of production of

milk, meat, fiber, or hide; for provision of services like land management or packing; or for research/teaching.

Interventions/Exposures: Included studies will be those using interventions/exposures of interest; items or experiences for environmental enrichment, under the five types: physical/structural, occupational/cognitive, feeding, sensory, or social. See “Study selection process” and Table 11 for details. Studies will be excluded if they do not have an intervention/exposure or comparison group.

Outcomes: Included studies will be those recording outcomes of interest; outcome measures relating to animal welfare: health-related parameters, affective state, and behavior and social/human interaction. See “Study selection process” section and Table 12 for details. Studies will be excluded if an outcome related to the above categories is not recorded.

Table 1: Databases and Interfaces Searched

Database	Interface	Date Coverage	Date Searched
CAB Abstracts* (included products: CAB ABSTRACTS, VetMed Resource, CABI Full Text, Global Health, Animal Health and Production Compendium (AHPC))	Ovid	1910 to Present	5 September 2024
BIOSIS Previews	Web of Science	1926 to Present	5 September 2024
Scopus	Scopus	1823 to Present	5 September 2024

Search strategy

Information sources and search strategy were determined with the assistance of UC Davis librarians with expertise in agricultural, veterinary, and biological sciences.

JT performed initial literature searches in August-September 2023 in order to determine specific search terms. “Environmental complexity” was found to be used in different ways relating to environmental enrichment: interchangeably with “environmental enrichment” overall (e.g., laboratory mammals review: Pritchett-Corning, 2019); when referring just to “physical/structural enrichment” (e.g., aquatic animals review: Zhang et al., 2022; nonhuman primates review: Bloomsmith et al., 1991); and when referring to providing a combination of different types of enrichment (e.g., laboratory mammals review: Pritchett-Corning, 2019; poultry review: Jacobs et al., 2023). Therefore, the search term “complex*” was included. It was then determined that neither “environment* enrich*” nor “environment* complex*” phrases alone can be used as search terms, as they in combination with “exp goats/” returned 13 and 1 results, respectively, in CAB Abstracts (Ovid; March 2024 search, with English language and through 2023 publication year limits). As a result, independent groups of search terms for each of the five types of environmental enrichment were created (Table 2). It should be noted that categories of environmental enrichment are not mutually exclusive (e.g., certain feeding enrichment can also function as occupational/cognitive enrichment).

References for search terms (Table 2) come from what is known to be biologically relevant for goats, including reviews regarding goat behavior (Zobel et al., 2019; Zobel and

Nawroth, 2020) and reviews and studies (some specific to goats, some regarding other species) relating to the environmental enrichment types.

Studies selected for data extraction will go through backward and forward citation searching. This will be done via Scopus, or manually, if necessary (Hirt et al., 2020). Relevant studies found in this manner will be assessed via the same screening process as noted below.

Table 2: Environmental enrichment search terms and associated references used for creating the database search strategies. Search terms were also added by assessing the indexing terms for 12 key articles in CAB Abstracts (Ovid; see Table 3).

Environmental enrichment type	Search terms	References
general enrichment terms	“enrich*” OR “complex*” OR “housing” OR “environment*” OR “goat housing” OR “animal husbandry” OR “physical activity”	Pritchett-Corning, 2019; Bloomsmith et al., 1991; Jacobs et al., 2023; Zobel et al., 2019; Zobel and Nawroth, 2020
physical/ structural	“hide*” OR “hiding” OR “shelter*” OR “box*” OR “hutch*” OR “platform*” OR “climb*” OR “elevated” OR “wall*” OR “partition*” OR “creche” OR “surface*” OR “substrate*” OR “bedding” OR “floor*”	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; Botreau et al., 2023b; NFACC, 2020; Spitzer et al., 2022
occupational/ cognitive	“cognit*” OR “learn*” OR “task*” OR “operant” OR “conditioning” OR “contra-freeload*” OR “contrafreeload*” OR “puzzle*” OR “walk*” OR “exercis*” OR “pasture*” OR “outdoor*” OR “auto* milk*”	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; Botreau et al., 2023b; NFACC, 2020; Oesterwind et al., 2016; Briefer et al., 2015
feeding	“feed*” OR “bipedal” OR “graz*” OR “brows*” OR “forag*” OR “taste” OR “tastes” OR “creep” OR “wean*” OR “suck*” OR “nurs*” OR “teat*”	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; NFACC, 2020; Ginane and Rørvang, 2023
sensory	“sensory” OR “sense” OR “senses” OR “visual” OR “auditory” OR “tactile” OR “olfact*” OR “brush*” OR “music” OR “radio*” OR “odor*” OR “odour*” OR “pheromone*” OR “video*” OR “movie*” OR “light*”	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; Ginane and Rørvang, 2023; Wells, 2009
social	“social*” OR “human-animal interaction*” OR “human animal interaction*” OR “human-animal relationship*” OR “human animal relationship*” OR “handl*” OR “gentl*” OR “hand-fe*” OR “bottle-fe*” OR “companion*” OR “group size” OR “stocking density” OR “dam” OR “dams” OR “maternal” OR “mother*” OR “rear*”	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; NFACC, 2020; Miranda-de la Lama and Mattiello, 2010; de Oliveira and Boivin, 2024

PRISMA-S Template (based on v1.0 retrieved from <https://osf.io/2ybwn/>)

Simultaneous Searches

Not applicable.

Item 2: Other Online Resources (As Needed)

Not applicable.

Manual Searching (searching relevant journals Table of Contents)

Not applicable.

Table 3: Citation Searching And Text Analysis

Article Citation:
Flint, M., & Murray, P. J. (2001). Lot-fed goats - the advantages of using an enriched environment. <i>Animal Production Science</i> , 41(4), 473–476. https://doi.org/10.1071/EA99119
Gomes, K. A. R., Valentim, J. K., Lemke, S. S. R., Dallago, G. M., Vargas, R. C., & Paiva, A. L. D. C. (2018). Behavior of Saanen dairy goats in an enriched environment. <i>Acta Scientiarum. Animal Sciences</i> , 40, e42454. https://doi.org/10.4025/actascianimsci.v40i1.42454
Miranda-de la Lama, G. C., Pinal, R., Fuchs, K., Montaldo, H. H., Ducoing, A., & Galindo, F. (2013). Environmental enrichment and social rank affects the fear and stress response to regular handling of dairy goats. <i>Journal of veterinary behavior</i> , 8(5), 342-348. https://doi.org/10.1016/j.jveb.2013.03.001
Aschwanden, J., Gygax, L., Wechsler, B., & Keil, N. M. (2009). Loose housing of small goat groups: Influence of visual cover and elevated levels on feeding, resting and agonistic behaviour. <i>Applied Animal Behaviour Science</i> , 119(3-4), 171-179. https://doi.org/10.1016/j.applanim.2009.04.005
Sutherland, M. A., Lowe, G. L., Cox, N. R., & Schütz, K. E. (2019). Effects of flooring surface and a supplemental heat source on location preference, behaviour and growth rates of dairy goat kids. <i>Applied animal behaviour science</i> , 217, 36-42. https://doi.org/10.1016/j.applanim.2019.05.003
Sutherland, M. A., Lowe, G. L., Watson, T. J., Ross, C. M., Rapp, D., & Zobel, G. A. (2017). Dairy goats prefer to use different flooring types to perform different behaviours. <i>Applied animal behaviour science</i> , 197, 24-31. https://doi.org/10.1016/j.applanim.2017.09.004
Oesterwind, S., Nürnberg, G., Puppe, B., & Langbein, J. (2016). Impact of structural and cognitive enrichment on the learning performance, behavior and physiology of dwarf goats (<i>Capra aegagrus hircus</i>). <i>Applied Animal Behaviour Science</i> , 177, 34-41. https://doi.org/10.1016/j.applanim.2016.01.006
Stachowicz, J., Gygax, L., Hillmann, E., Wechsler, B., & Keil, N. M. (2018). Dairy goats use outdoor runs of high quality more regardless of the quality of indoor housing. <i>Applied Animal Behaviour Science</i> , 208, 22-30. https://doi.org/10.1016/j.applanim.2018.08.012
Cellier, M., Nielsen, B. L., Duvaux-Ponter, C., Freeman, H. B., Hannaford, R., Murphy, B., O'Connor, E., Cote K. R. L., Neave, H. W., & Zobel, G. (2022). Browse or browsing: Investigating goat preferences for feeding posture, feeding height and feed type. <i>Frontiers in Veterinary Science</i> , 9, 1032631. https://doi.org/10.3389/fvets.2022.1032631

Neave, H. W., von Keyserlingk, M. A., Weary, D. M., & Zobel, G. (2018). Feed intake and behavior of dairy goats when offered an elevated feed bunk. *Journal of dairy science*, 101(4), 3303-3310. <https://doi.org/10.3168/jds.2017-13934>

Boivin, X., & Braastad, B. O. (1996). Effects of handling during temporary isolation after early weaning on goat kids' later response to humans. *Applied Animal Behaviour Science*, 48(1-2), 61-71. [https://doi.org/10.1016/0168-1591\(95\)01019-X](https://doi.org/10.1016/0168-1591(95)01019-X)

Toinon, C., Waiblinger, S., & Rault, J. L. (2021). Maternal deprivation affects goat kids' stress coping behaviour. *Physiology & Behavior*, 239, 113494. <https://doi.org/10.1016/j.physbeh.2021.113494>

Process: JT identified 12 key studies: 3 representing general environmental enrichment, 3 representing physical/structural enrichment, 2 representing occupational/cognitive enrichment, 2 representing feeding enrichment, and 2 representing social enrichment. Studies representing sensory enrichment were not identified. Search terms were added by assessing the indexing terms for these 12 key articles in CAB Abstracts (Ovid), with SR-Accelerator (<https://sr-accelerator.com/>) used to check for any additional commonly used words.

Contacts (Researchers contacted for additional information)

Not applicable.

Additional Methodologies Not Listed Above

For papers that pass screening, backward and forward citation searching will be performed.

Process: Studies selected for data extraction will go through backward and forward citation searching. This will be done via Scopus, or manually, if necessary (Hirt et al., 2020). Relevant studies found in this manner will be assessed via the same screening process as noted below.

Limits and Restrictions

Date and Time Period: 1960-present (date of search: 5 September 2024).

Language: English.

Publication status: Published, peer-reviewed studies (i.e., excluding grey literature).

Species Included: Goats.

Study Design: Analytical experimental or observational (cross-sectional, cohort, case-control, or hybrid) study designs, involving data from direct observation or from pre-existing sources/databases (i.e., excluding descriptive and review papers).

Database Subset: None.

Pre-specified cut-off or saturation point for results: None.

Other Restrictions: None.

Table 4: Search Filters

Database	Interface	Search Filters Applied
CAB Abstracts	Ovid	Language, years, publication type
BIOSIS Previews	Web of Science	Language, years, document type, taxa
Scopus	Scopus	Language, years, document type

Full Search Strategy:

Table 5: Information Sources

Database	Interface	Date Coverage	Date Searched
CAB Abstracts* (included products: CAB ABSTRACTS, VetMed Resource, CABI Full Text, Global Health, Animal Health and Production Compendium (AHPC))	Ovid	1910 to Present	5 September 2024
BIOSIS Previews	Web of Science	1926 to Present	5 September 2024
Scopus	Scopus	1823 to Present	5 September 2024

Table 6: Search Database - CAB Abstracts (Ovid)

Search ID	Terms (copy and paste)	Results
#1 species	("goat" OR "goats" OR "Capra hircus" OR "Capra aegagrus hircus" OR "C. hircus" OR "C. a. hircus").ti,ab. OR "goats".od.	120,700
#2 general enrichment terms	("enrich*" OR "complex*" OR "housing" OR "environment*" OR "goat housing" OR "animal husbandry" OR "physical activity").ti,ab. OR ("goat housing" OR "animal husbandry" OR "physical activity").de.	1,897,506
#3 physical/ structural enrichment	("hide*" OR "hiding" OR "shelter*" OR "box*" OR "hutch*" OR "platform*" OR "climb*" OR "elevated" OR "wall*" OR "partition*" OR "creche" OR "surface*" OR "substrate*" OR "bedding" OR "floor*").ti,ab.	1,379,423
#4 occupational/ cognitive enrichment	("cognit*" OR "learn*" OR "task*" OR "operant" OR "conditioning" OR "contra-free-load*" OR "contrafreeload*" OR "puzzle*" OR "walk*" OR "exercis*" OR "pasture*" OR "outdoor*" OR "auto* milk*").ti,ab.	507,326

#5 feeding enrichment	("feed*" OR "bipedal" OR "graz*" OR "brows*" OR "forag*" OR "taste" OR "tastes" OR "creep" OR "wean*" OR "suck*" OR "nurs*" OR "teat*").ti,ab.	1,237,438
#6 sensory enrichment	("sensory" OR "sense" OR "senses" OR "visual" OR "auditory" OR "tactile" OR "olfact*" OR "brush*" OR "music" OR "radio*" OR "odor*" OR "odour*" OR "pheromone*" OR "video*" OR "movie*" OR "light*").ti,ab.	916,890
#7 social enrichment	("social*" OR "human-animal interaction*" OR "human animal interaction*" OR "human-animal relationship*" OR "human animal relationship*" OR "handl*" OR "gentl*" OR "hand-fe*" OR "bottle-fe*" OR "companion*" OR "group size" OR "stocking density" OR "dam" OR "dams" OR "maternal" OR "mother*" OR "rear*").ti,ab.	783,851
#8 welfare and behavior	("welfare" OR "wellbeing" OR "well-being" OR "behav*" OR "prefer*" OR "motivat*").ti,ab. OR ("animal welfare" OR "animal behaviour").de.	912,647
#9	#2 OR #3 OR #4 OR #5 OR #6 OR #7	5,187,751
#10	#1 AND #9 AND #8	4,769
#11	limit #10 to english language	3,835
#12	limit #11 to yr="1960 - Current"	3,677
#13	#12 AND "Journal article" [Publication Type]	3,173
Link to search	<a a="" goat"+or+"goats"+or+"capra+hircus"+or+"capra+aegagrus+hircus"+or+"c.+hircus"+or+"c.+a.+hircus").ti.ab.+or+"goats".od.+%0a++++("enrich"+or+"complex"+or+"housing"+or+"environment"+or+"goat+housing"+or+"animal+husbandry"+or+"physical+activity").ti.ab.+or+("goat+housing"+or+"animal+husbandry"+or+"physical+activity").de.+%0a++++("hide"+or+"hiding"+or+"shelter"+or+"box"+or+"hutch"+or+"platform"+or+"climb"+or+"elevated"+or+"wall"+or+"partition"+or+"creche"+or+"surface"+or+"substrate"+or+"bedding"+or+"floor*").ti.ab.+%0a++++("cognit"+or+"learn"+or+"task"+or+"operant"+or+"conditioning"+or+"contra-freeload"+or+"contrafreeload"+or+"puzzle"+or+"walk"+or+"exercis"+or+"pasture"+or+"outdoor"+or+"auto+milk*").ti.ab.+%0a++++("feed"+or+"bipedal"+or+"graz"+or+"brows"+or+"forag"+or+"taste"+or+"tastes"+or+"creep"+or+"wean"+or+"suck"+or+"nurs"+or+"teat*").ti.ab.+%0a++++("sensory"+or+"sense"+or+"senses"+or+"visual"+or+"auditory"+or+"tactile"+or+"olfact"+or+"brush"+or+"music"+or+"radio"+or+"odor"+or+"odour"+or+"pheromone"+or+"video"+or+"movie"+or+"light*").ti.ab.+%0a++++("social"+or+"human-animal+interaction"+or+"human+animal+interaction"+or+"human-animal+relationship"+or+"human+animal+relationship"+or+"handl"+or+"gentl"+or+"hand-fe"+or+"bottle-fe"+or+"companion"+or+"group+size"+or+"stocking<="" href="http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=y&D=cabz&PAGE=main&NEWS=n&ID=&PASSWORD=&SEARCH=++++(">	

	+density"+or+"dam"+or+"dams"+or+"maternal"+or+"mother*"+or+"rear*"). ti.ab.+%0A++++("welfare"+or+"wellbeing"+or+"well-being"+or+"behav*"+ or+"prefer*"+or+"motivat*").ti.ab.+or+("animal+welfare"+or+"animal+beha viour").de.+%0A++++2+or+3+or+4+or+5+or+6+or+7+%0A++++1+and+9+ and+8+%0A++++10+%0A++++limit+11+to+english+language+%0A++++1 2+%0A++++limit+13+to+yr="1960+-Current"+%0A++++14+and+"Journal +article".sa_pabt.+	
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Table 7: Search Database - BIOSIS Previews

Search ID	Terms (copy and paste)	Results
#1 species	TS=(“goat” OR “goats” OR “Capra hircus” OR “Capra aegagrus hircus” OR "C. hircus" OR "C. a. hircus")	75,001
#2 general enrichment terms	TS=(“enrich*” OR “complex*” OR “housing” OR “environment*” OR “animal husbandry” OR “physical activit*”)	6,719,836
#3 physical/ structural enrichment	(TI=(“hide*” OR “hiding” OR “shelter*” OR “box*” OR “hutch*” OR “platform*” OR “climb*” OR “elevated” OR “wall*” OR “partition*” OR “creche” OR “surface*” OR “substrate*” OR “bedding” OR “floor*”)) OR AB=(“hide*” OR “hiding” OR “shelter*” OR “box*” OR “hutch*” OR “platform*” OR “climb*” OR “elevated” OR “wall*” OR “partition*” OR “creche” OR “surface*” OR “substrate*” OR “bedding” OR “floor*”)	3,160,915
#4 occupational/ cognitive enrichment	(TI=(“cognit*” OR “learn*” OR “task*” OR “operant” OR “conditioning” OR “contra-freeload*” OR “contrafreeload*” OR “puzzle*” OR “walk*” OR “exercis*” OR “pasture*” OR “outdoor*” OR “auto* milk*”)) OR AB=(“cognit*” OR “learn*” OR “task*” OR “operant” OR “conditioning” OR “contra-freeload*” OR “contrafreeload*” OR “puzzle*” OR “walk*” OR “exercis*” OR “pasture*” OR “outdoor*” OR “auto* milk*”)	1,279,287
#5 feeding enrichment	(TI=(“feed*” OR “bipedal” OR “graz*” OR “brows*” OR “forag*” OR “taste” OR “tastes” OR “creep” OR “wean*” OR “suck*” OR “nurs*” OR “teat*”)) OR AB=(“feed*” OR “bipedal” OR “graz*” OR “brows*” OR “forag*” OR “taste” OR “tastes” OR “creep” OR “wean*” OR “suck*” OR “nurs*” OR “teat*”)	1,099,444
#6 sensory enrichment	(TI=(“sensory” OR “sense” OR “senses” OR “visual” OR “auditory” OR “tactile” OR “olfact*” OR “brush*” OR “music” OR “radio*” OR “odor*” OR “odour*” OR “pheromone*” OR “video*” OR “movie*” OR “light*”)) OR AB=(“sensory” OR “sense” OR “senses” OR “visual” OR “auditory” OR “tactile” OR “olfact*” OR “brush*” OR “music” OR “radio*” OR “odor*” OR “odour*” OR “pheromone*” OR “video*” OR “movie*” OR “light*”)	2,453,804

#7 social enrichment	(TI=(“social*” OR “human-animal interaction*” OR “human animal interaction*” OR “human-animal relationship*” OR “human animal relationship*” OR “handl*” OR “gentl*” OR “hand-fe*” OR “bottle-fe*” OR “companion*” OR “group size” OR “stocking density” OR “dam” OR “dams” OR “maternal” OR “mother*” OR “rear*”)) OR AB=(“social*” OR “human-animal interaction*” OR “human animal interaction*” OR “human-animal relationship*” OR “human animal relationship*” OR “handl*” OR “gentl*” OR “hand-fe*” OR “bottle-fe*” OR “companion*” OR “group size” OR “stocking density” OR “dam” OR “dams” OR “maternal” OR “mother*” OR “rear*”)	1,057,010
#8 welfare and behavior	TS=(“welfare” OR “wellbeing” OR “well-being” OR “behav*” OR “prefer*” OR “motivat*”)	3,798,210
#9	#2 OR #3 OR #4 OR #5 OR #6 OR #7	12,338,601
#10	#1 AND #9 AND #8	4,285
#11	#10 Refined by: Languages: English	3,988
#12	#11 AND PY=(1960-2024)	3,933
#13	#12 AND Article (Document Types)	3,553
#14	#13 and TA=(bovidae)	3,088
Link to search	https://www.webofscience.com/wos/biosis/summary/5307b36d-a065-40b8-96a2-11d5b8c97f2d-010637a4fa/relevance/1	

Table 8: Search Database - Scopus

Search ID	Terms (copy and paste)	Results
#1 species	TITLE-ABS-KEY (“goat” OR “goats” OR “Capra hircus” OR “Capra aegagrus hircus” OR "C. hircus" OR "C. a. hircus")	86,804
#2 general enrichment terms	TITLE-ABS-KEY (“enrich*” OR “complex*” OR “housing” OR “environment*” OR “animal husbandry” OR “physical activit*”)	13,314,190
#3 physical/ structural enrichment	TITLE-ABS (“hide*” OR “hiding” OR “shelter*” OR “box*” OR “hutch*” OR “platform*” OR “climb*” OR “elevated” OR “wall*” OR “partition*” OR “creche” OR “surface*” OR “substrate*” OR “bedding” OR “floor*”)	11,031,460
#4 occupational/ cognitive enrichment	TITLE-ABS (“cognit*” OR “learn*” OR “task*” OR “operant” OR “conditioning” OR “contra-freeload*” OR “contrafreeload*” OR “puzzle*” OR “walk*” OR “exercis*” OR “pasture*” OR “outdoor*” OR “auto* milk*”)	6,493,067

#5 feeding enrichment	TITLE-ABS ("feed*" OR "bipedal" OR "graz*" OR "brows*" OR "forag*" OR "taste" OR "tastes" OR "creep" OR "wean*" OR "suck*" OR "nurs*" OR "teat*")	3,139,433
#6 sensory enrichment	TITLE-ABS ("sensory" OR "sense" OR "senses" OR "visual" OR "auditory" OR "tactile" OR "olfact*" OR "brush*" OR "music" OR "radio*" OR "odor*" OR "odour*" OR "pheromone*" OR "video*" OR "movie*" OR "light*")	8,384,257
#7 social enrichment	TITLE-ABS ("social*" OR "human-animal interaction*" OR "human animal interaction*" OR "human-animal relationship*" OR "human animal relationship*" OR "handl*" OR "gentl*" OR "hand-fe*" OR "bottle-fe*" OR "companion*" OR "group size" OR "stocking density" OR "dam" OR "dams" OR "maternal" OR "mother*" OR "rear*")	4,898,574
#8 welfare and behavior	TITLE-ABS-KEY ("welfare" OR "wellbeing" OR "well-being" OR "behav*" OR "prefer*" OR "motivat*")	9,188,730
#9	#2 OR #3 OR #4 OR #5 OR #6 OR #7	36,433,192
#10	#1 AND #9 AND #8	4,483
#11	#10 AND (LIMIT-TO (LANGUAGE , "English"))	4,223
#12	#11 AND (PUBYEAR > 1959 AND PUBYEAR < 2025)	4,210
#13	#12 AND (LIMIT-TO (DOCTYPE , "ar"))	3,614
Copy and paste	(TITLE-ABS-KEY ("goat" OR "goats" OR "Capra hircus" OR "Capra aegagrus hircus" OR "C. hircus" OR "C. a. hircus")) AND ((TITLE-ABS-KEY ("enrich*" OR "complex*" OR "housing" OR "environment*" OR "animal husbandry" OR "physical activit*")) OR (TITLE-ABS ("hide*" OR "hiding" OR "shelter*" OR "box*" OR "hutch*" OR "platform*" OR "climb*" OR "elevated" OR "wall*" OR "partition*" OR "creche" OR "surface*" OR "substrate*" OR "bedding" OR "floor*")) OR (TITLE-ABS ("cognit*" OR "learn*" OR "task*" OR "operant" OR "conditioning" OR "contra-freeload*" OR "contrafreeload*" OR "puzzle*" OR "walk*" OR "exercis*" OR "pasture*" OR "outdoor*" OR "auto* milk*")) OR (TITLE-ABS ("feed*" OR "bipedal" OR "graz*" OR "brows*" OR "forag*" OR "taste" OR "tastes" OR "creep" OR "wean*" OR "suck*" OR "nurs*" OR "teat*")) OR (TITLE-ABS ("sensory" OR "sense" OR "senses" OR "visual" OR "auditory" OR "tactile" OR "olfact*" OR "brush*" OR "music" OR "radio*" OR "odor*" OR "odour*" OR "pheromone*" OR "video*" OR "movie*" OR "light*")) OR (TITLE-ABS ("social*" OR "human-animal interaction*" OR "human animal interaction*" OR "human-animal relationship*" OR "human animal relationship*" OR "handl*" OR "gentl*" OR "hand-fe*" OR "bottle-fe*" OR "companion*" OR "group size" OR "stocking density" OR "dam" OR "dams" OR "maternal" OR "mother*" OR "rear*"))) AND (TITLE-ABS-KEY ("welfare" OR	

	"wellbeing" OR "well-being" OR "behav*" OR "prefer*" OR "motivat*")) AND PUBYEAR > 1959 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (DOCTYPE , "ar"))	
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Table 9: Database Search Results

Database	Total Records	Total Records after deduplication	Deduplication software/ methodology
CAB Abstracts	3,173	3,165	Covidence
BIOSIS Previews	3,088	5,174	Covidence
Scopus	3,614	6,646	Covidence

Prior work

Not applicable.

Updates

Not applicable.

Search Designers

UC Davis Librarian(s) or Information Specialist(s) involved in the process: Erik Fausak, Ruth Gustafson, Beth Tweedy. Additional input from content experts in the project: Dr. Carly Moody, Dr. Alda Pires, Dr. Cassandra Tucker, Dr. Noelia Silva Del Rio.

Peer Review

The protocol has been reviewed by UC Davis librarian Erik Fausak.

Table 10: Records to Screen

Total Records	Total Records after deduplication	Deduplication software/methodology
9,875	6,646	Covidence

Data management

The review software program Covidence will be used to facilitate the removal of duplicate studies and the selection/exclusion process with corresponding PRISMA-ScR diagram. Microsoft Excel will be used for data extraction.

Study selection process (screening and eligibility)

Research assistants will undergo protocol screening training with JT. The screening protocol will be initially tested with 100 studies to ensure agreement, and edits will be made where needed. Disagreements on exclusion will be decided by an additional reviewer. JT and the research assistants will repeat testing for one study every 500 studies to ensure consistency with

the screening protocol over time. The studies resulting from the database searches will be screened in two levels:

Level 1: Title/Abstract screening. Independent researchers (JT and research assistants) will assess each title/abstract and answer the following questions as “yes,” “no,” or “maybe.”

1. Does the study indicate that the population of focus is domesticated goats under human care raised for the production of milk, meat, fiber, and hide; for provision of services like land management and packing; or for research/teaching purposes?
2. Is the study published in a peer-reviewed scientific journal?
3. Is the study of an analytical experimental or observational (cross-sectional, cohort, case-control, or hybrid) design?
4. Does the study indicate at least one intervention/exposure regarding the provision of an item/experience for enhancing the physical/structural, occupational/cognitive, feeding, sensory, or social characteristics of the goats’ environment? (See below and Table 11 for definitions.)

❖ “Yes” or “maybe” for all 4 questions: study retained for Level 2 screening.

❖ Both reviewers agree at least 1 of the 4 questions receives “no”: study excluded.

Level 2: Full-text screening. Independent researchers (JT and research assistants) will assess each full text and answer the following questions as “yes” or “no.” Only studies which receive “yes” for all 4 questions will have data extracted.

1. Is the full text of the study available in English?
2. Does the study indicate that the population of focus is domesticated goats under human care raised for the production of milk, meat, fiber, and hide; for provision of services like land management and packing; or for research/teaching purposes?
3. Does the study indicate at least one intervention/exposure regarding the provision of an item/experience for enhancing the physical/structural, occupational/cognitive, feeding, sensory, or social characteristics of the goats’ environment? (See below and Table 11 for definitions.)
4. Does the study indicate at least one outcome relating to goat health or behavior? (See below and Table 12 for examples.)

Defining environmental enrichment: For the purposes of this scoping review, environmental enrichment will be defined as items and/or experiences provided to enhance an animals’ environment, with the goal of improving its physical or mental well-being, or allowing species-typical behavior (Bloomsmith 1991, Newberry, 1995; Mandel et al., 2016; Vickery et al., 2022). Because there are various definitions of environmental enrichment (e.g., notions of it being above “basic care”), this paper will use a broad definition to capture the literature that exists for a more comprehensive review. Defining environmental enrichment (i.e., determining interventions/exposures) will be further clarified by two points: 1) Environmental enrichment is denoted by the animal being able to perceive the change (Botreau et al., 2023a) and/or involves an element of choice (Decker et al., 2023). For example, adding mineral supplementation to feed rations to meet nutritional requirements would not be considered environmental enrichment for the present review. However, providing a mineral/salt lick in a pen allows for both self-selection and an alternative way of obtaining this element of nutrition, which would consider it as a form of feeding enrichment. 2) While recommended practices exist for domesticated goats under

human care, either some aspects of environmental enrichment are not covered, or there are differences between said recommendations and other ideals of standard welfare/what is considered “natural.” For example, care guidelines across countries largely recommend to separate newborn dairy goat kids from their dams (as reviewed by Bélanger-Naud and Vasseur, 2021), whereas the process of separation/weaning may not otherwise begin for several weeks to months (Poindron et al., 2007; Miranda-de la Lama and Mattiello, 2010). Therefore, dam-kid contact is valid to be considered in this scoping review as social enrichment, as it differs from typical management in this context. Definitions for different types of environmental enrichment are listed in Table 11, and will be used for screening.

Table 11: Definitions of the different types of environmental enrichment and associated references. “Overall complexity” was added as a separate type to indicate papers that may include multiple types of environmental enrichment as the intervention/exposure (e.g., comparing “enriched” versus “barren” environments).

Environmental enrichment type	Definition	References
Physical/ structural	modifications to the housing space/environment that increase physical complexity	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; Botreau et al., 2023b; NFACC, 2020; Spitzer et al., 2022
Occupational/ cognitive	items/experiences that involve performing a task (often for a reward), learning/training, objects to manipulate, or those that encourage physical exercise	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; Botreau et al., 2023b; NFACC, 2020; Oesterwind et al., 2016; Briefer et al., 2015
Feeding	food items delivered in different ways (often to encourage foraging), offering novel types of food or food with different tastes, or offering diversity/variety of feeds	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; NFACC, 2020; Ginane and Rørvang, 2023
Sensory	items/experiences meant to stimulate senses of sight, sound, touch, or smell	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; Ginane and Rørvang, 2023; Wells, 2009
Social	interaction with others of the same species, with animals of different species, or with humans	Bloomsmith et al., 1991; Mandel et al., 2016; Botreau et al., 2023a; NFACC, 2020; Miranda-de la Lama and Mattiello, 2010; de Oliveira and Boivin, 2024
Overall complexity	providing 2+ types of environmental enrichment at once, or rotating out different forms of items or those of different types	E.g., Gomes et al., 2018

Defining outcomes: Table 12 is a non-exhaustive list of example terms related to outcome measures for determining how environmental enrichment affects goats, and will be used for Level 2 screening. It incorporates the “Three Circles” (Fraser et al., 1997) and “Five Domains” (Mellor et al., 2020) paradigms of animal welfare in order to cover a broad scope of welfare-related outcomes. References for Table 2 were also used in the creation of Table 12, with

additional references as noted. These categories of outcome measures are also not mutually exclusive (e.g., conditions of health-related parameters and affective state can be indicated by certain behaviors). For the purposes of this scoping review, outcomes may be measured at any point (e.g., at the same stage as enrichment application, or later in life/after enrichment application).

Table 12: Example outcome measure terms which studies may use for determining how environmental enrichment affects goats, and associated references.

Animal welfare (Fraser et al., 1997; Ede et al., 2019; Mellor et al., 2020; Minnig et al., 2021; Papageorgiou and Simitzis, 2022; Decker et al., 2023; Dawkins, 2023)		
Health-related parameters	Affective state	Behavior and social/human interaction
disease, injury, mortality, immunity, nutrition, body condition, hair coat condition, lameness, hoof/claw health, growth, body condition score, physiological stress (e.g., thermoregulation), reproductive performance, milk production or quality, live weight, fiber quality, longevity	emotions, arousal, valence, cognitive bias, exploration, satiety, play, comfort, calm, confident, exhaustion, depression, pain, fear, anxiety, frustration	natural behavior, species-specific behavior, highly motivated behavior, abnormal behavior, conspecific (agonistic or affiliative) interactions, frequency/duration of use, anticipatory response, investigation, use/interest over time, proximity to, preference test, choice test, behavioral flexibility, human handling, human-animal interaction, human-animal relationship

Data charting process (data extraction)

Independent researchers (JT and research assistants) will perform data extraction for each selected study to be sorted using Excel spreadsheets. The information will include the following:

- Study/publication characteristics
- Study population
- Study intervention(s)/exposure(s)
- Study outcome(s)

Data items and synthesis of results

Extracted data will be broken down into the following categories, with interventions/exposures and outcomes as described previously:

- Study/publication characteristics
 - Author(s)
 - Year of publication
 - Country study took place
 - Study design
 - Analytical experimental
 - Analytical observational
 - Cross-sectional
 - Cohort
 - Case-control
 - Hybrid
 - Data source
 - Direct observation

- Using pre-existing sources/databases
- Study population
 - Production/use of goats
 - Milk
 - Meat
 - Fiber
 - Hide
 - Land management
 - Packing
 - Research/teaching
 - Other
 - Dual- or multi-purpose
 - Specify combinations of uses
 - Breed of goats
 - Sex of goats
 - Male/buck
 - Breeding vs wethered
 - Female/doe
 - Age group/life stage of goats (USDA, n.d.)
 - Kid (under 12 months of age)
 - Yearling (12-24 months of age)
 - Adult (over 24 months of age)
 - Pregnant/lactating/breeding
 - Goat housing details
 - Setting
 - Indoor
 - Outdoor
 - Indoor/outdoor mixed access
 - Group physical structure (Miranda-de la Lama and Mattiello, 2010):
 - Pen/group size or stocking density
 - Mixed age/life stage or sex
- Study intervention(s)/exposure(s)
 - Physical/structural enrichment
 - Occupational/cognitive enrichment
 - Feeding enrichment
 - Sensory enrichment
 - Social enrichment
 - Overall complexity
 - Specify combinations of environmental enrichment types
- Study outcome(s)
 - Aspects of animal welfare
 - Health-related parameters (e.g., disease, body condition score, parameters specific to production type)
 - Affective state (e.g., cognitive bias, fear)

- Behavior and social/human interaction (e.g., agonistic interactions, interaction with the enrichment, human-animal relationship)
- Other - Effects of environmental enrichment on human-centric factors were not included with search terms or welfare-related outcomes for screening. However, they will be included as outcome measures to be extracted, where present.
 - Other human-centric factors (e.g., economics, feasibility, practicality, public perception) (Van de Weerd and Day, 2009; Riber et al., 2018)
- Time frame over which environmental enrichment is provided and outcome is measured (Cantor et al., 2019)
 - Short-term effects: outcome(s) measured during environmental enrichment provision or within days/weeks/the same age group or life stage
 - Long-term effects/longitudinal: outcome(s) measured after environmental enrichment provision, over or after one or more years or the next life stage

The process of data searching, selection, and exclusion will be depicted in a flow diagram. Categorization of selected studies by the publication characteristics, population, intervention(s)/exposure(s), and outcome(s) will be illustrated via tables and figures (descriptive statistics).

Risk of bias in individual studies

Not applicable for this scoping review.

Confidence in cumulative evidence

Not applicable for this scoping review.

DISCUSSION

This scoping review will provide a descriptive summary of the environmental enrichment literature for domesticated goats. Data extraction will identify gaps in the literature and areas for future research, and assess whether enough information exists to conduct a subsequent systematic review.

Competing interests

The authors have no competing interests to declare for this scoping review.

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Role of funder or sponsor

Not applicable for this scoping review.

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