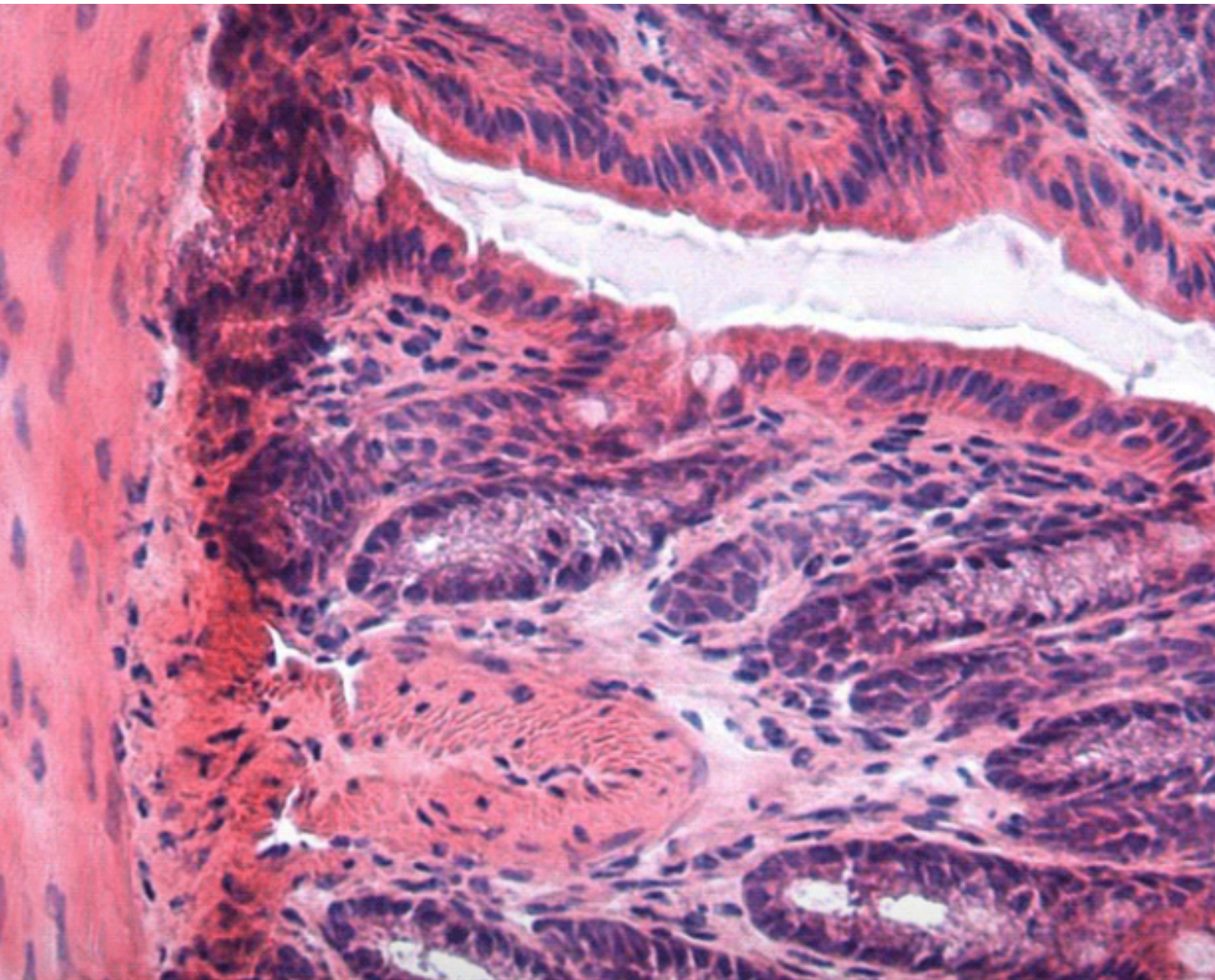
TdB Labs.

# DSS40

## A Key Reagent in Colitis Studies

Written by: Jeanne Hochart, MSc
Reviewed by: Nasim Najjarzadeh, PhD



TdB Labs.

# Table of Contents

## Inflammatory Bowel Disease (IBD)

The human gastrointestinal (GI) tract is continuously exposed to a wide range of bacteria and toxins from food and the environment, making it highly susceptible to various diseases. Among these, the occurrence of inflammatory bowel disease (IBD) is growing and includes conditions such as ulcerative colitis (UC) and Crohn's disease, which are chronic inflammatory conditions driven by uncontrolled immune responses, with gut inflammation resulting from interactions between the gut microbiome and immune cells (1). Genetics, environmental conditions, and intestinal microbiota influence the development of IBD. The higher prevalence of IBD in North America and Europe compared to Asia and Africa suggests a strong link to the Western lifestyle.

UC and Crohn's disease are differentiated by their location and depth, which affect the bowel wall. Crohn's disease can impact any part of the gastrointestinal tract, from the mouth to the anus, most commonly affecting the terminal ileum. In contrast, UC is typically confined to the mucosa and submucosa of the colon, usually beginning in the rectum and extending upward along the colon. Symptoms of both types mainly include diarrhea, rectal bleeding, abdominal pain, fatigue, and weight loss; however, they may have many extraintestinal manifestations as well (2).

## Ulcerative Colitis (UC)

Ulcerative colitis (UC) is a heterogeneous disease that can be classified into two distinct types: extensive ulcerative colitis and distal proctocolitis. The pathogenesis often begins with uncontrolled T-cell responses targeting specific strains of commensal enteric bacteria. The onset or reactivation of UC is typically associated with the disruption of the mucosal barrier by environmental factors, which ultimately trigger immune responses. These responses include the infiltration of immune cells and the release of pro-inflammatory cytokines (3).

While treatment for IBD is generally not curative, the primary goal is to achieve disease remission or alleviate symptoms. For UC patients, commonly prescribed drugs work by suppressing the immune system to control inflammation (4). Unfortunately, the efficacy of these drugs is limited by adverse effects such as increased risks of infections, lymphoma, and nonmelanoma skin cancer.

Consequently, experimental studies are crucial to uncover the causes and mechanisms of IBD, potentially leading to alternative treatments or more effective drugs for UC patients. Research on animal models has provided valuable insights into disease establishment, progression, and the testing of new therapies (3).

## Induction of colitis in animal models

Experimental models have significantly improved our understanding of UC. On a more technical level, there are different ways to induce colitis in experimental models.

### 1. Chemical induction:

These chemicals disrupt the intestinal epithelial barrier, leading to inflammation and damage to the intestinal tissue. The main ones are the following:

- Dextran sulfate sodium: It can induce colitis by disrupting the epithelial monolayer lining of the large intestine (5).
- Trinitrobenzene sulfonic acid (TNBS): This hapten reagent induces colitis by causing a delayed-type hypersensitivity reaction (Th1 response) (6).
- Oxazolone colitis: This hapten reagent triggers a Th2-mediated immune response associated with severe mucosal damage (7).
- Acetic acid: This reagent directly causes colitis by damaging the colonic mucosa (8).

### 2. Bacterial induction:

These bacteria can colonize the intestines and trigger an inflammatory response, leading to the development of colitis.

- *Salmonella typhimurium*: This bacterium induces colitis by infecting the intestinal mucosa (9).
- *Adherent–invasive E. coli*: This bacterium triggers colitis by adhering to and invading the intestinal epithelial cells (10).
- *Helicobacter hepaticus*: This bacterium causes colitis by inducing an immune response in the intestines (11).
- *Citrobacter rodentium*: This bacterium induces colitis by colonizing the colonic mucosa and triggering an inflammatory response (12).

# The Dextran Sulfate Sodium compound

Dextran sulfate sodium (DSS) is a negatively charged sulfated polysaccharide with a molecular weight ranging from 5 to 2000 kDa. Known for inducing colitis, DSS is used in various animal models like mice, rats, hamsters, guinea pigs, rabbits, and chickens. Its colitogenic potential depends on its molecular weight and degree of sulfation.

The effectiveness of DSS-induced colitis depends on factors such as dosage (usually 1%–5%), duration of exposure (acute or chronic) (13), the strain of tested animals (1), gender of animals (male mice are more susceptible) (1), and microbial environment of animals (14). The negative charge of DSS can affect the colonic epithelium, consequently increasing the epithelial barrier permeability. Additionally, gut morphology, such as villous microarchitecture, crypts, and mucus production, is impaired (1).

Although the exact mechanism by which DSS triggers colitis remains unclear, it is hypothesized that this water-soluble polysaccharide disrupts the epithelial monolayer lining of the large intestine, allowing the dissemination of proinflammatory intestinal contents into underlying tissue. In other words, the gut epithelium becomes leaky, which allows for immune cells to infiltrate and release pro-inflammatory cytokines (Figure 1).

Furthermore, there is an increase in reactive oxygen species (ROS) in the cytosol, which has been shown to play a significant role in the development and progression of colitis. ROS are highly reactive molecules that can disrupt the intestinal barrier, triggering endoplasmic reticulum stress and apoptosis in intestinal cells. This mechanical change induces the penetration of harmful substances through the underlying tissue, consequently (15). Thus, DSS has become frequently used as a colitis inducer in mice, as well as other animal models, over recent years (1).

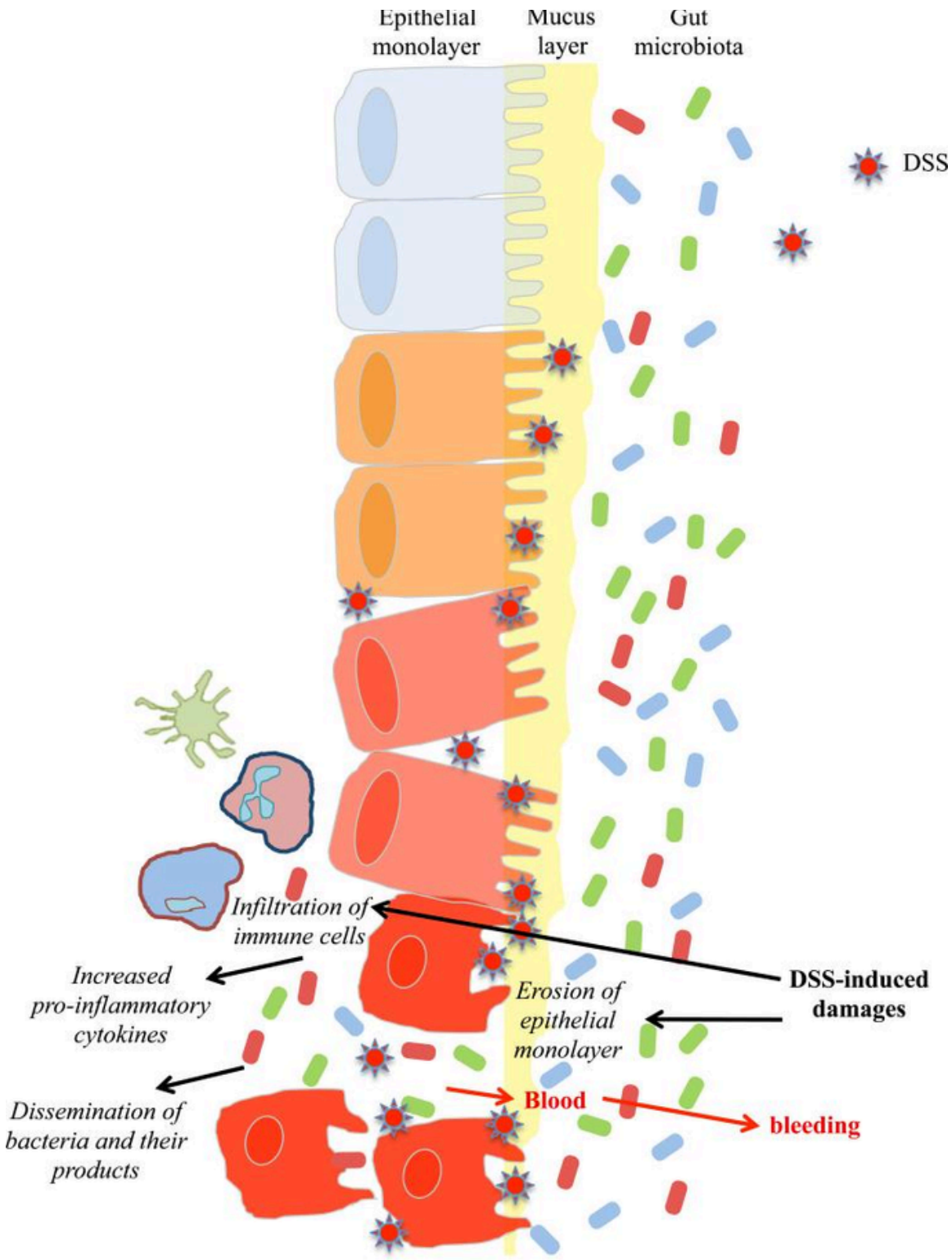



**Figure 1.** DSS mechanism of colitis induction (1)

# Advantages of DSS-Induced Colitis Models in IBD Research

DSS-induced colitis models have shown great advantages for the study of IBD and colitis aetiology. DSS stands as the most attractive in comparison with other chemical colitis inducers because of several factors:

- Ease of administration: DSS is typically administered in drinking water, with no need for invasive procedures like surgery, hence making the handling a lot easier than using TNBS, which needs to be administered by enteral feeding via a catheter (16).
- Rapid induction of colitis: Usually within 5-7 days of administration. This rapid onset allows researchers to study the early phases of colitis and the inflammatory response (1).
- Reproducibility: DSS-induced colitis is highly reproducible, allowing for consistent results across different experiments and laboratories when using standardized protocols (5).
- Control over disease severity: It can be controlled by adjusting the concentration and duration of DSS administration, allowing researchers to study different degrees of inflammation and disease progression (16).
- Simulate acute and chronic colitis: Depending on the concentration and duration of DSS exposure, researchers can induce either acute or chronic colitis (5).
- Similar histopathological features to human IBD: the symptoms and pathophysiology of DSS-induced colitis observed in experimental models closely resemble those found in humans. DSS-induced colitis in rodents exhibits similar histopathological features to human IBD, including mucosal ulceration, crypt distortion, infiltration of inflammatory cells, and epithelial damage, making it a relevant model for studying IBD pathogenesis and testing potential therapies (5).
- Cost-effective: relatively inexpensive compared to other methods of inducing colitis (17).

Altogether, DSS-induced colitis models stand as very attractive models due to their rapidity, simplicity, reproducibility, and controllability. It offers a time-honoured approach to studying IBD's pathogenesis in an in vivo model. Furthermore, it is a convenient way to compare the different aspects of UC by tuning the disease to its acute, chronic, or relapsing behaviour. Nevertheless, our understanding of the disease relies on the combination of various animal models (1).

# How to induce colitis with DSS

Studies on animal models, as well as clinical trials, have significantly improved our understanding of the disease and provided important insights relevant to treatment development. An ideal experimental model must exhibit all the features of human disease, including specific symptoms, and must respond to available therapies to ensure effective translation to the human setting. There are several experimental models available for the study of colitis, including spontaneous and induced models. A spontaneous animal model naturally develops a disease without external intervention, while an induced animal model involves deliberately introducing a disease through external means. Spontaneous models include, for instance, IL-10, IL-2, and TLR5-deficient mice. As it is mentioned earlier, the induction of colitis in animals is done using chemicals such as DSS, TNBS, and oxazolone (18).

Several mouse models are readily available; some are defined as spontaneous, and others are induced. As mentioned earlier, the development of colitis in the animal model will be dependent on the molecular weight, the degree of sulphation of DSS, its dosage, and the duration of administration. There are some optimal conditions for the induction of colitis regardless of the animal model chosen (18).

## Optimal conditions

The optimal conditions to induce colitis in an animal model are reached when using DSS with a molecular weight from 36 to 50 kDa. DSS with a lower molecular weight will result in milder colitis, and mice may recover from it. Nevertheless, choosing the right molecular weight is essential since larger molecules will not have the capacity to penetrate through colonic tissue, whereas smaller ones will have a poor distribution (18). Both male and female mice can develop colitis. Nevertheless, it is recommended to use 8-week-old mice with a C57BL/6J and BALB/c background due to their prevalence in previous studies.

**Table 1.** Summary of factors influencing the effectiveness of DSS in inducing colitis (adapted from Eichele DD, et al. (20))

| Factors | Variables | Description |
|---|---|---|
| DSS | Molecular weight | 36 to 50 kDa |
| | Concentration | 1 to 5% |
| | Duration of administration | Different exposure cycles |
| | Manufacturer/batch | Different potency |
| Host | Model/strain | Some animals/strains are more susceptible than others |
| Environment | Housing conditions | Group vs individual unit<br>Cage changes |
| | Microbial state | Germ-free vs specific pathogen-free vs wild-type |

Younger mice are not recommended because they are more likely to have reduced consumption of water, hence reducing their exposure to DSS. Additionally, there is some evidence that males are more susceptible to colitis induction by DSS than female mice (19).

Similarly, the environment can influence the effectiveness of DSS in inducing colitis. For instance, research has shown that some enteric bacteria could play a role in clearing acute colitis. Therefore, the environment in which the animal model is housed has an influence on DSS effectiveness in inducing colitis (19). When optimal conditions are met, the disease onset usually occurs within 3 to 7 days following DSS administration. Nevertheless, this always depends on the dosage, frequency of administration, and animal strain (Table 1).

### Preparation and administration

To prepare the solution, the appropriate amount of DSS powder should be dissolved in autoclaved water. It is important to thoroughly mix the substance to obtain a clear solution. Additionally, depending on the animal model, the volumes needed may vary. For instance, mice are known to drink about 7 to 10 mL a day. Furthermore, it is essential to monitor the water uptake from your different animal groups. In fact, it was previously shown that some genetically modified mouse strains may consume more DSS water than their control group (1, 18).

## Disease severity and measurement

### A. Macroscopic evaluation: Physiological symptoms and inflammatory score

Different techniques are available to assess the severity of the disease and confirm that DSS successfully triggered colitis. The main features that first need to be monitored are body weight, colon length, spleen weight, diarrhea, and rectal bleeding.

It is possible to visualize the inflammation state in vivo, using the Coloview system. This system is a miniendoscope that enables the monitoring and grading of diseases such as colitis and colon cancer. The device can be introduced via the mouse's anus, under anesthesia, and capture images of the colon to visualise the surface of the crypts and the pit pattern architecture. In this way, it is possible to identify any colonic mucosal damage resulting from colitis onset (21) (Table 2).

**Table 2.** Disease Activity Index (DAI) following macroscopic observations to assess colitis severity (data extracted from reference 22))

| Feature | Score | Description |
|---|---|---|
| Weight | 0 | No loss |
| | 1 | 5-10% |
| | 2 | 10-15% |
| | 3 | 15-20% |
| | 4 | 20% |
| Feces | 0 | Normal |
| | 2 | Loose stool |
| | 4 | Diarrhea |
| Rectal bleeding | 0 | No blood |
| | 2 | Presence |
| | 4 | Gross blood |

## B. Inflammation assessment

### a. Histology

To confirm the presence of inflammation, it is recommended to carry out some histopathological analyses of the colonic tissue. The most widely used technique is to stain paraffin-embedded samples with haematoxylin-eosin (HE). Via this staining, researchers can look at the presence of ulcerations, inflammatory cells such as lymphocytes or macrophages, and loss of the crypt epithelium. These results can then be used to assess the degree of inflammation (Table 3) (Figure 2).

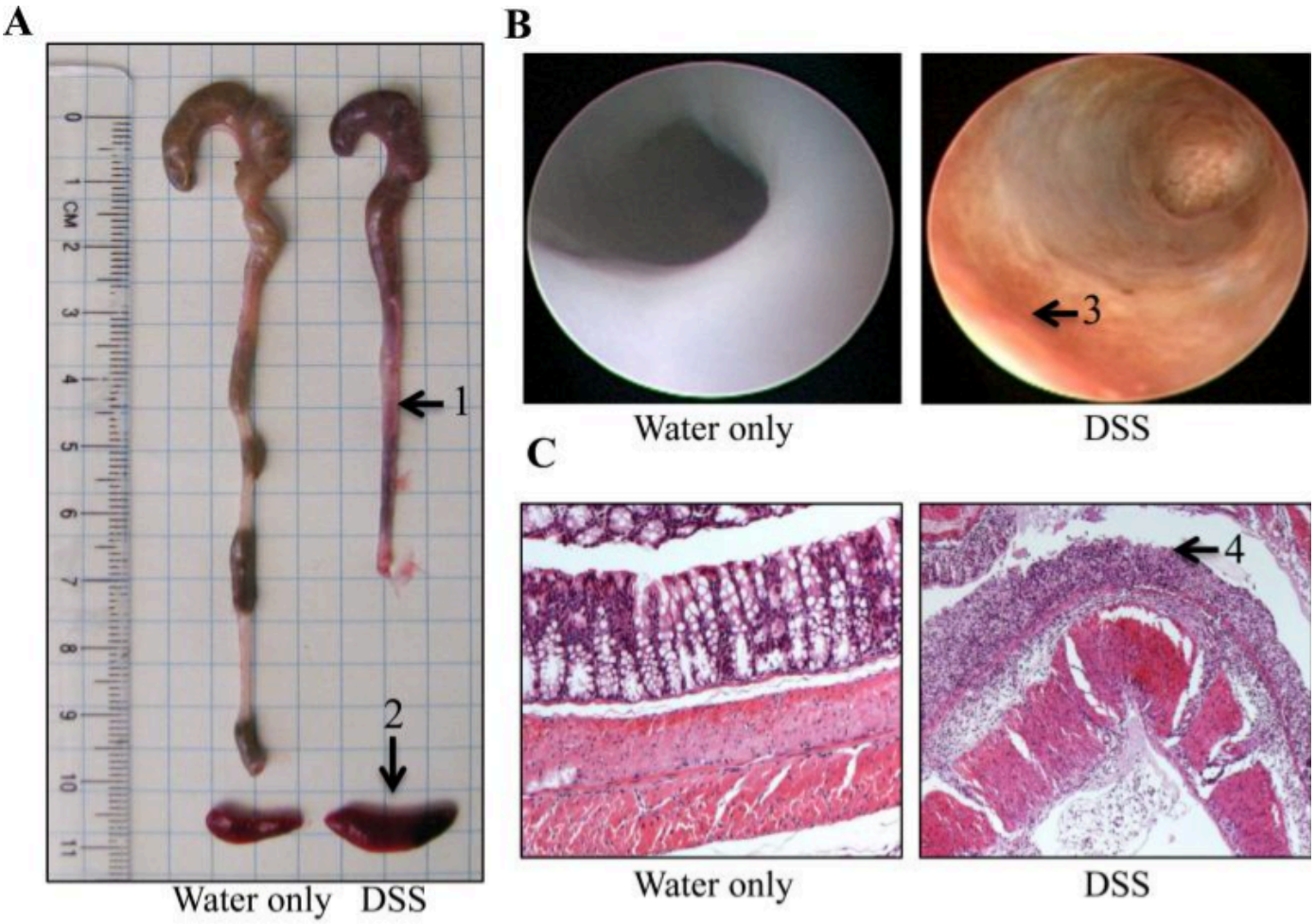



**Figure 2**. Different assessments of colitis disease severity. **(A)** Measurement of colon length **(B)** Endoscopic examination **(C)** Histopathology analysis (1)

**Table 3.** Inflammation score based on H&E staining of colonic tissue sections (created with data from (23).

| Feature | Score | Description |
|---|---|---|
| Crypt architecture | 0 | Normal |
| | 3 | Severe crypt distortion with loss of entire crypts |
| Inflammatory cell infiltration | 0 | Normal |
| | 3 | Dense inflammatory infiltrate |
| Muscle thickening | 0 | Base of crypt sits on the muscularis mucosae |
| | 3 | Marked muscle thickening present |
| Goblet cell depletion | 0 | Absent |
| | 1 | Present |
| Crypt abscess | 0 | Absent |
| | 1 | Present |

### b. Myeloperoxidase Activity

A complementary analysis of the inflammation can involve a myeloperoxidase (MPO) assay. MPO is an enzyme that has been shown to correlate with the number of neutrophils in histological sections. Indeed, this enzyme gets released from lysosomal azurophilic granules upon activation and stimulation of the immune system. Therefore, this assay can be used as a marker for inflammation in gut samples in murine models.

The enzyme activity can be determined through a colorimetric assay and analyzed at 460nm. Besides measuring MPO activity, levels of MPO at the mRNA and protein levels can be quantified by qPCR and ELISA. Nevertheless, it is important to note that the amount of protein does not always reflect its enzymatic activity (24).

### c. Permeability Assessment

Moreover, since DSS is known to disrupt the colonic epithelial lining, FITC-dextran (4 to 40 kDa) can be utilized to assess the barrier's permeability. To do so, FITC-dextran is administered to the animal model by oral gavage, after dissolution in PBS buffer. Blood samples can be collected, and the serum can be assessed for the presence of FITC-dextran by measuring the fluorescence intensity. The more abundant the molecule, the more permeable the intestinal barrier becomes in response to DSS40. In fact, the permeability correlates with the fluorescence intensity (25).

## C. Molecular Assessment

### a. Inflammatory cytokines

Since DSS colitis is characterized by inflammation, it is known that cytokine and chemokine production is increased as soon as DSS is administered to the animal. These increased levels of cytokines, such as IL-4, IL-6, IL-10, or IFNγ, will further enhance the inflammation. On the other hand, other cytokine levels, especially TNF-α and IL-17, are decreased. Cytokine levels can be evaluated via an enzyme-linked immunosorbent assay (ELISA) (23).

### b. Detection of stool IgA

As previously described, the levels of IgA in feces samples of UC patients are increased, unlike in serum samples. Therefore, IgA concentrations can be measured by ELISA, after feces sample extraction. To do some, the feces must be homogenised in PBS and stained with FITC-conjugated anti-IgA antibodies (26).

### c. Genetic assessment

To get a deeper understanding of the colitis state, it is possible to analyse the gene expression of the MUC gene family. It was shown that MUC gene expression can be altered in UC models. This is because mucins are influenced by cytokines and bacteria. Since UC is characterized by a change in the immunological profile and bacterial factors, mucin gene expression is ultimately affected too. For instance, it was shown that MUC 1, 3, and 4 gene expressions were significantly increased during acute colitis. Therefore, these genes can serve as markers of early inflammation (27).

## Protocols

To study colitis in animal models, different protocols can be employed depending on the desired onset and duration of the disease. These protocols vary in terms of DSS concentration, duration of exposure, and the cyclic nature of administration. Below are the protocols for inducing acute and chronic colitis (28):

### A. Acute colitis

In the case of an acute onset of the disease, 5 ml of DSS solution will have to be administered daily for up to 8 days. On days 3 and 5, the DSS solution will be discarded and replaced with fresh DSS solution. It is crucial to measure the leftover DSS solution in each group's bottle, as the difference in DSS consumption can account for changes in colitis activity. This acute protocol is often characterized by a significant reduction in body weight and colon length, followed by intensified diarrhea and rectal bleeding from day 8 (Figure 3).

### B. Chronic colitis

When using 2.5% DSS, colitis with a chronic profile will be induced. Although the DSS sulphation proportion is lower, the animal will be exposed to it for a longer period of time, up to 35 days, which accounts for the chronic profile of the disease. The overall inflammation is milder, but a reduced colon length with an enlargement of the spleen is observed (Figure 4).

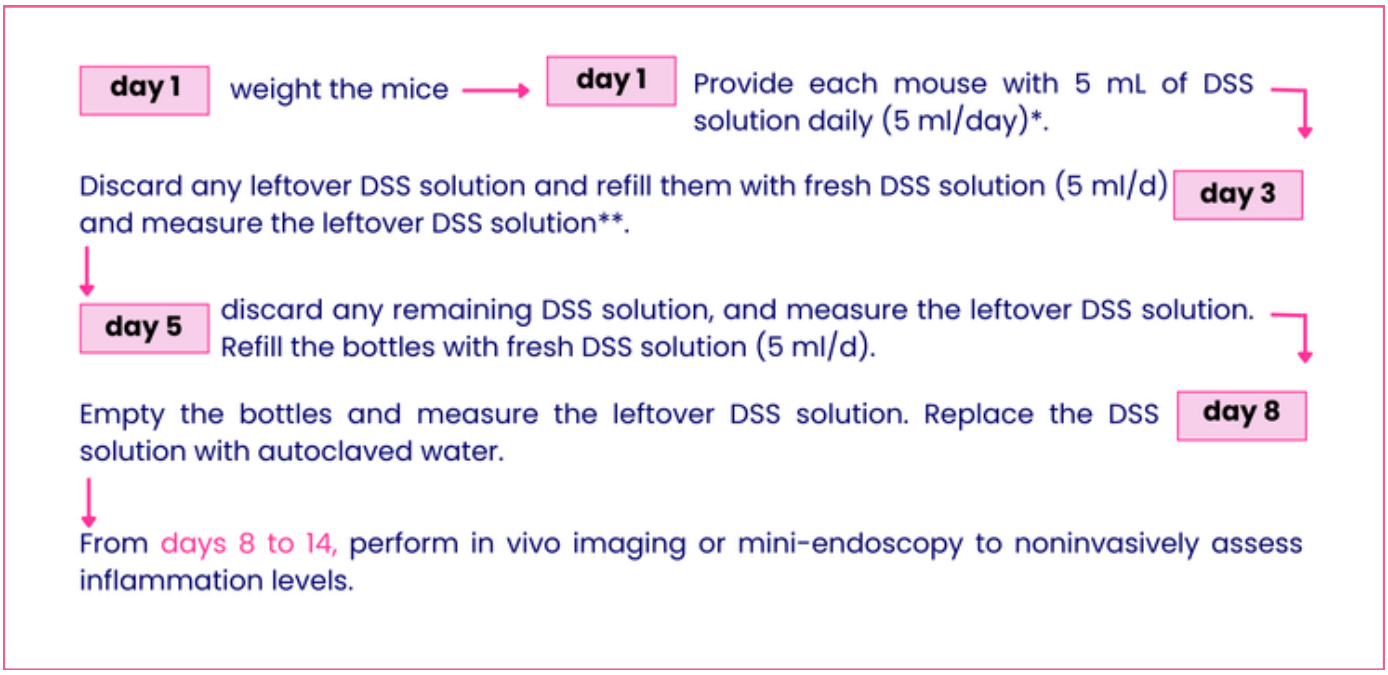



**Figure 3.** Protocol to induce acute colitis with DSS (28)

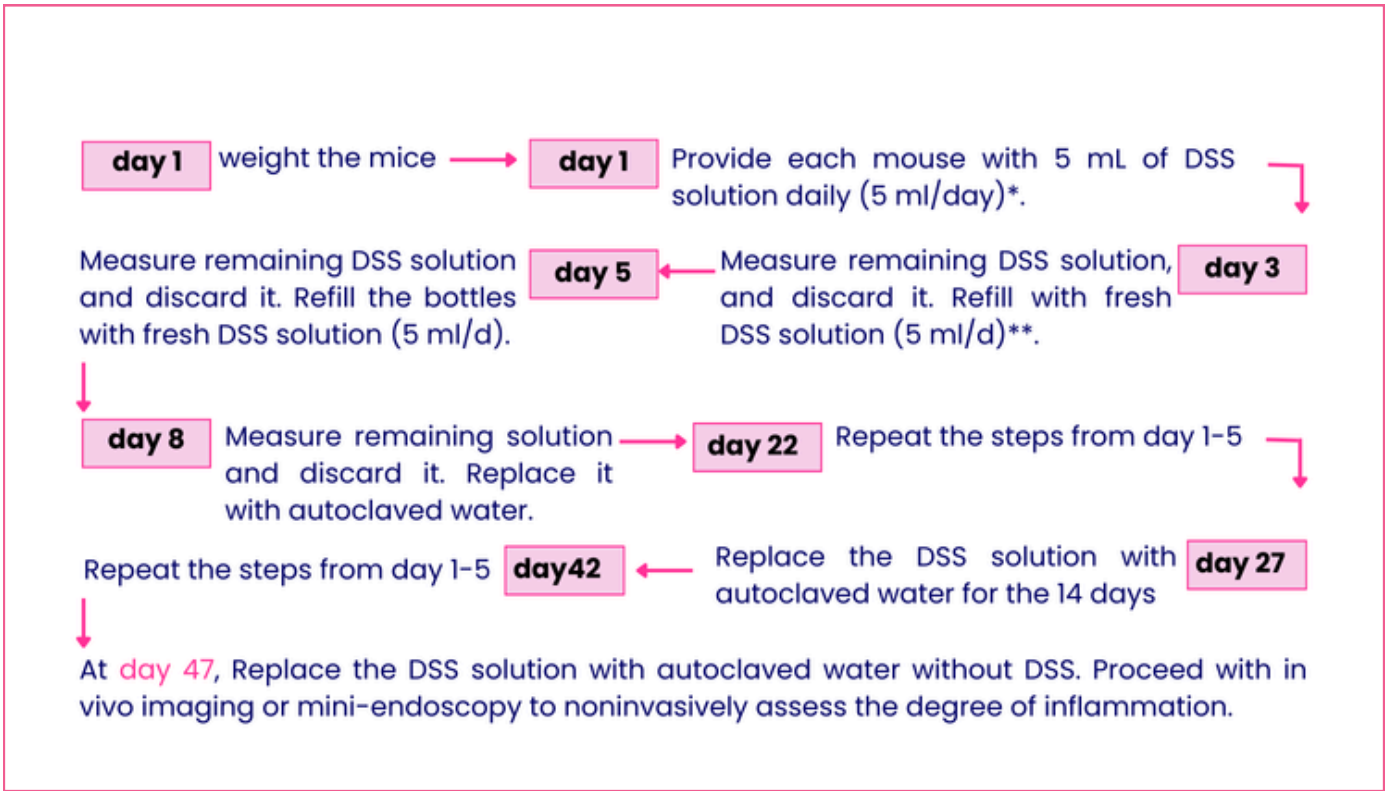



**Figure 4.** Protocol to induce chronic colitis with DSS (28)

***** Control mice should receive tap water without DSS

****** Measure the leftover DSS water in each group's bottles to ensure colitis activity changes aren't due to differences in DSS consumption. This step is crucial as genetic differences or treatments may affect DSS water intake.

# DSS40 in different animal models

When inducing colitis in an animal model, it is important to study the susceptibility of the strain since different species and strains react differently to DSS. The DSS molecular weight, sulphur content, and concentration must be adjusted accordingly (Table 4).

Several experiments have been carried out on different animals, including mice, rats, guinea pigs, hamsters, rabbits, and chickens. For instance, while mice and rats usually exhibit lesions in the colon, guinea pigs are more susceptible, and colitis develops in the cecum. If no symptoms are observed after 7 days of DSS administration, it is recommended to increase the DSS concentration. The estimated volume of water consumption for murine models is 7-10 ml per day for mice and per 100 g bodyweight for rats.

**Table 4.** Guidelines for DSS concentration and duration of administration for successful colitis induction in different experimental models.

| Animal model | Strain | Sex | Age | Dosage | Days | References |
|---|---|---|---|---|---|---|
| Mouse | C57BL/6J | M/F | 8 | 2 to 5 % | 3 to 7 days | (1) |
| | DPIV-/- mice | NA | 6 to 7 weeks | 2% | 6 days | (29) |
| | APN KO | M | 8 to 10 | 2.5% | 7 days | (30) |
| | BALB/c | F | 6 to 9 | 3 to 10% | 7 days | (31, 32) |

| Animal model | Strain | Sex | Age | Dosage | Days | Ref. |
|---|---|---|---|---|---|---|
| Mouse | BALB/c | M/F | 8 | 3 to 5 % | 4 to 7 days | (1) |
| | BALB/c | M | 7 | 1% | 10 days | (33) |
| | BALB/c A Jcl | M | 6 | 5% | 8 days | (34) |
| | BALB/c Cr Slc | F | 6 to 7 | 5% | 7 days | (35) |
| | C.B17 SCID | F | 7 to 8 | 5% | 8 days | (36) |
| | C3H/HeJ | F | 6 to 8 | 5% | 7 days | (36) |
| | C57/B6 | F | 8 | 2% | 7 days | (37) |
| | C57BL/6 | M | 8 | 3-5% | 3 to 14 days | (38, 39) |
| | C57BL/6 | F | 7 to 12 | 3% | 5 days | (40) |
| | C57BL/6 AhR null | M | 3 months | 3.5% | 7 days | (41) |
| | C57BL/6J | M | 8 to 10 | 3 to 5% | 7 days | (42) |

| Animal model | Strain | Sex | Age | Dosage | Days | Ref. |
|---|---|---|---|---|---|---|
| Mouse | C57BL/6J | F | 6 to 8 | 3% | 5 days | (43) |
| | CBA/J | F | 8 to 9 | 3-10% | 7 days | (31, 44) |
| | CCR9(-/-); CCL25 (-/-) | NA | NA | 2% | 7 days | (45) |
| | IL-5 -/- | NA | NA | 2.5-5% | 8 days | (46) |
| | Nrf2 -/- | NA | 9 to 12 | 1% | 7 days | (47) |
| | Swiss albino | M | 28-30g | 5% | 7 days | (48) |
| | Swiss-Webster | F | 8 | 5% | 5 to 7 days | (49) |

| Animal model | Strain | Sex | Age | Dosage | Days | Ref. |
|---|---|---|---|---|---|---|
| Rat | ACI | M | 5 weeks | 5 to 10% | 14 days | (50) |
| | Sprague-Dawley | M | 220-280g | 2-5% | 5-14 days | (51-57) |

| Animal model | Strain | Sex | Age | Dosage | Days | Ref. |
|---|---|---|---|---|---|---|
| Rat | Wistar | M | 100-120g | 1-2% | 2 weeks to 6 months | (58, 59) |
| | Wistar | M/F | 80-100g | 3-5% | 6-10 days | (60, 61, 63) |
| | Wistar | F | 175-225g | 3-5% | 10 days | (62) |
| Hamster | Syrian | M | 8-9 weeks | 1% | 100 days | (64) |
| | Syrian | M | 6-8 weeks | 2-5% | 6 days | (65) |
| Rabbit | Himalayan | F | 1.9–2.1 kg | 0.1 | NA | (66) |
| | New Zealand | F | 1.9–2.1 kg | 0.1 | NA | (67) |
| Chicken | Chinese yellow broiler | M | NA | 0.75-2.5% | NA | (68) |
| Pig | Yorkshire | NA | 7 days | 1.25g/kg | 5 | (69) |

# References


1. Chassaing B, Aitken JD, Malleshappa M, Vijay-Kumar M. Dextran sulfate sodium (DSS)-induced colitis in mice. Curr Protoc Immunol. 2014 Feb 4;104:15.25.1-15.25.14. doi: 10.1002/0471142735.im1525s104. PMID: 24510619; PMCID: PMC3980572.

2. Perler BK, Ungaro R, Baird G, Mallette M, Bright R, Shah S, Shapiro J, Sands BE. Presenting symptoms in inflammatory bowel disease: descriptive analysis of a community-based inception cohort. BMC Gastroenterol. 2019 Apr 2;19(1):47. doi: 10.1186/s12876-019-0963-7. Erratum in: BMC Gastroenterol. 2020 Dec 3;20(1):406. doi: 10.1186/s12876-020-01526-2. PMID: 30940072; PMCID: PMC6446285.

3. Sartor RB. Mechanisms of disease: pathogenesis of Crohn's disease and ulcerative colitis. Nat Clin Pract Gastroenterol Hepatol. 2006 Jul;3(7):390-407. doi: 10.1038/ncpgasthep0528. PMID: 16819502.

4. Raine T, Bonovas S, Burisch J, Kucharzik T, Adamina M, Annese V, Bachmann O, Bettenworth D, Chaparro M, Czuber-Dochan W, Eder P, Ellul P, Fidalgo C, Fiorino G, Gionchetti P, Gisbert JP, Gordon H, Hedin C, Holubar S, Iacucci M, Karmiris K, Katsanos K, Kopylov U, Lakatos PL, Lytras T, Lyutakov I, Noor N, Pellino G, Piovani D, Savarino E, Selvaggi F, Verstockt B, Spinelli A, Panis Y, Doherty G. ECCO Guidelines on Therapeutics in Ulcerative Colitis: Medical Treatment. J Crohns Colitis. 2022 Jan 28;16(1):2-17. doi: 10.1093/ecco-jcc/jjab178. PMID: 34635919.

5. Yang C, Merlin D. Unveiling Colitis: A Journey through the Dextran Sodium Sulfate-induced Model. Inflamm Bowel Dis. 2024 May 2;30(5):844-853. doi: 10.1093/ibd/izad312. PMID: 38280217; PMCID: PMC11063560.

6. Modesto R, Estarreja J, Silva I, Rocha J, Pinto R, Mateus V. Chemically Induced Colitis-Associated Cancer Models in Rodents for Pharmacological Modulation: A Systematic Review. J Clin Med. 2022 May 12;11(10):2739. doi: 10.3390/jcm11102739. PMID: 35628865; PMCID: PMC9146029.

7. Meroni E, Stakenborg N, Gomez-Pinilla PJ, De Hertogh G, Goverse G, Matteoli G, Verheijden S, Boeckxstaens GE. Functional characterization of oxazolone-induced colitis and survival improvement by vagus nerve stimulation. PLoS One. 2018 May 23;13(5):e0197487. doi: 10.1371/journal.pone.0197487. PMID: 29791477; PMCID: PMC5965883.

8. Rafeeq M, Murad HAS, Abdallah HM, El-Halawany AM. Protective effect of 6-paradol in acetic acid-induced ulcerative colitis in rats. BMC Complement Med Ther. 2021 Jan 13;21(1):28. doi: 10.1186/s12906-021-03203-7. Erratum in: BMC Complement Med Ther. 2021 Feb 10;21(1):60. doi: 10.1186/s12906-021-03241-1. PMID: 33441125; PMCID: PMC7805070.

9. Li J, Yang Y, Zhang X, Yang Y, Wu Z. Fisetin alleviates Salmonella typhimurium-induced colitis through the TLR2/TLR4-NF-κB pathway, regulating microbiota, and repressing intracellular bacterial proliferation by focal adhesion kinase. Eur J Nutr. 2025 Mar 19;64(3):128. doi: 10.1007/s00394-025-03602-3. PMID: 40106033.

10. Rolhion N, Darfeuille-Michaud A. Adherent-invasive Escherichia coli in inflammatory bowel disease. Inflamm Bowel Dis. 2007 Oct;13(10):1277-83. doi: 10.1002/ibd.20176. PMID: 17476674.

11. Tomczak MF, Erdman SE, Davidson A, Wang YY, Nambiar PR, Rogers AB, Rickman B, Luchetti D, Fox JG, Horwitz BH. Inhibition of Helicobacter hepaticus-induced colitis by IL-10 requires the p50/p105 subunit of NF-kappa B. J Immunol. 2006 Nov 15;177(10):7332-9. doi: 10.4049/jimmunol.177.10.7332. PMID: 17082652.

12. Wlodarska M, Willing B, Keeney KM, Menendez A, Bergstrom KS, Gill N, Russell SL, Vallance BA, Finlay BB. Antibiotic treatment alters the colonic mucus layer and predisposes the host to exacerbated Citrobacter rodentium-induced colitis. Infect Immun. 2011 Apr;79(4):1536-45. doi: 10.1128/IAI.01104-10. Epub 2011 Feb 14. PMID: 21321077; PMCID: PMC3067531.

13. Xu HM, Huang HL, Liu YD, Zhu JQ, Zhou YL, Chen HT, Xu J, Zhao HL, Guo X, Shi W, Nie YQ, Zhou YJ. Selection strategy of dextran sulfate sodium-induced acute or chronic colitis mouse models based on gut microbial profile. BMC Microbiol. 2021 Oct 16;21(1):279. doi: 10.1186/s12866-021-02342-8. PMID: 34654370; PMCID: PMC8520286.

14. Ozkul C, Ruiz VE, Battaglia T, Xu J, Roubaud-Baudron C, Cadwell K, Perez-Perez GI, Blaser MJ. A single early-in-life antibiotic course increases susceptibility to DSS-induced colitis. Genome Med. 2020 Jul 25;12(1):65. doi: 10.1186/s13073-020-00764-z. PMID: 32711559; PMCID: PMC7382806.

15. Wan Y, Yang L, Jiang S, Qian D, Duan J. Excessive Apoptosis in Ulcerative Colitis: Crosstalk Between Apoptosis, ROS, ER Stress, and Intestinal Homeostasis. Inflamm Bowel Dis. 2022 Mar 30;28(4):639-648. doi: 10.1093/ibd/izab277. PMID: 34871402.

16. Cochran KE, Lamson NG, Whitehead KA. Expanding the utility of the dextran sulfate sodium (DSS) mouse model to induce a clinically relevant loss of intestinal barrier function. PeerJ. 2020 Mar 10;8:e8681. doi: 10.7717/peerj.8681. PMID: 32195049; PMCID: PMC7069414.

17. Martin JC, Bériou G, Josien R. Dextran Sulfate Sodium (DSS)-Induced Acute Colitis in the Rat. Methods Mol Biol. 2016;1371:197-203. doi: 10.1007/978-1-4939-3139-2_12. PMID: 26530802.

18. Axelsson LG, Landström E, Bylund-Fellenius AC. Experimental colitis induced by dextran sulphate sodium in mice: beneficial effects of sulphasalazine and olsalazine. Aliment Pharmacol Ther. 1998 Sep;12(9):925-34. doi: 10.1046/j.1365-2036.1998.00357.x. PMID: 9768537.

19. Hoffmann JC, Pawlowski NN, Kühl AA, Höhne W, Zeitz M. Animal models of inflammatory bowel disease: an overview. Pathobiology. 2002-2003;70(3):121-30. doi: 10.1159/000068143. PMID: 12571415.

20. Eichele DD, Kharbanda KK. Dextran sodium sulfate colitis murine model: An indispensable tool for advancing our understanding of inflammatory bowel diseases pathogenesis. World J Gastroenterol. 2017 Sep 7;23(33):6016-6029. doi: 10.3748/wjg.v23.i33.6016. PMID: 28970718; PMCID: PMC5597494.

21. Rival M, Cherbut C. MUC genes are differently expressed during onset and maintenance of inflammation in dextran sodium sulfate-treated mice. Dig Dis Sci. 2006 Feb;51(2):381-9. doi: 10.1007/s10620-006-3142-y. PMID: 16534686.

22. Ghia JE, Li N, Wang H, Collins M, Deng Y, El-Sharkawy RT, Côté F, Mallet J, Khan WI. Serotonin has a key role in pathogenesis of experimental colitis. Gastroenterology. 2009 Nov;137(5):1649-60. doi: 10.1053/j.gastro.2009.08.041. Epub 2009 Aug 23. PMID: 19706294.

23. Kim JJ, Shajib MS, Manocha MM, Khan WI. Investigating intestinal inflammation in DSS-induced model of IBD. J Vis Exp. 2012 Feb 1;(60):3678. doi: 10.3791/3678. PMID: 22331082; PMCID: PMC3369627.

24. Hanning, N. et al. (2023). Measuring Myeloperoxidase Activity as a Marker of Inflammation in Gut Tissue Samples of Mice and Rat. Bio-protocol 13(13): e4758. DOI: 10.21769/BioProtoc.4758.

25. Yan Y, Kolachala V, Dalmasso G, Nguyen H, Laroui H, Sitaraman SV, Merlin D. Temporal and spatial analysis of clinical and molecular parameters in dextran sodium sulfate induced colitis. PLoS One. 2009 Jun 29;4(6):e6073. doi: 10.1371/journal.pone.0006073. PMID: 19562033; PMCID: PMC2698136.

26. Lin R, Chen H, Shu W, Sun M, Fang L, Shi Y, Pang Z, Wu W, Liu Z. Clinical significance of soluble immunoglobulins A and G and their coated bacteria in feces of patients with inflammatory bowel disease. J Transl Med. 2018 Dec 17;16(1):359. doi: 10.1186/s12967-018-1723-0. PMID: 30558634; PMCID: PMC6296095.

27. Hoebler C, Gaudier E, De Coppet P, Rival M, Cherbut C. MUC genes are differently expressed during onset and maintenance of inflammation in dextran sodium sulfate-treated mice. Dig Dis Sci. 2006 Feb;51(2):381-9. doi: 10.1007/s10620-006-3142-y. PMID: 16534686.

28. Wirtz S, Popp V, Kindermann M, Gerlach K, Weigmann B, Fichtner-Feigl S, Neurath MF. Chemically induced mouse models of acute and chronic intestinal inflammation. Nat Protoc. 2017 Jul;12(7):1295-1309. doi: 10.1038/nprot.2017.044. Epub 2017 Jun 1. PMID: 28569761.

29. Yazbeck R, Howarth GS, Butler RN, Geier MS, Abbott CA. Biochemical and histological changes in the small intestine of mice with dextran sulfate sodium colitis. J Cell Physiol. 2011 Dec;226(12):3219-24. doi: 10.1002/jcp.22682. PMID: 21351101.

30. Nishihara T, Matsuda M, Araki H, Oshima K, Kihara S, Funahashi T, Shimomura I. Effect of adiponectin on murine colitis induced by dextran sulfate sodium. Gastroenterology. 2006 Sep;131(3):853-61. doi: 10.1053/j.gastro.2006.06.015. PMID: 16952554.

31. Okayasu I, Hatakeyama S, Yamada M, Ohkusa T, Inagaki Y, Nakaya R. A novel method in the induction of reliable experimental acute and chronic ulcerative colitis in mice. Gastroenterology. 1990 Mar;98(3):694-702. doi: 10.1016/0016-5085(90)90290-h. PMID: 1688816.

32. Kitajima S, Takuma S, Morimoto M. Changes in colonic mucosal permeability in mouse colitis induced with dextran sulfate sodium. Exp Anim. 1999 Jul;48(3):137-43. doi: 10.1538/expanim.48.137. PMID: 10480018.

33. Rochat T, Bermúdez-Humarán L, Gratadoux JJ, Fourage C, Hoebler C, Corthier G, Langella P. Anti-inflammatory effects of Lactobacillus casei BL23 producing or not a manganese-dependant catalase on DSS-induced colitis in mice. Microb Cell Fact. 2007 Jul 20;6:22. doi: 10.1186/1475-2859-6-22. PMID: 17659075; PMCID: PMC1949835.

34. Araki Y, Mukaisyo K, Sugihara H, Fujiyama Y, Hattori T. Increased apoptosis and decreased proliferation of colonic epithelium in dextran sulfate sodium-induced colitis in mice. Oncol Rep. 2010 Oct;24(4):869-74. doi: 10.3892/or.2010.869. PMID: 20811666.

35. Kitajima S, Takuma S, Morimoto M. Histological analysis of murine colitis induced by dextran sulfate sodium of different molecular weights. Exp Anim. 2000 Jan;49(1):9-15. doi: 10.1538/expanim.49.9. PMID: 10803356.

36. Dieleman LA, Ridwan BU, Tennyson GS, Beagley KW, Bucy RP, Elson CO. Dextran sulfate sodium-induced colitis occurs in severe combined immunodeficient mice. Gastroenterology. 1994 Dec;107(6):1643-52. doi: 10.1016/0016-5085(94)90803-6. PMID: 7958674.

37. Bamba S, Andoh A, Ban H, Imaeda H, Aomatsu T, Kobori A, Mochizuki Y, Shioya M, Nishimura T, Inatomi O, Sasaki M, Saitoh Y, Tsujikawa T, Araki Y, Fujiyama Y. The severity of dextran sodium sulfate-induced colitis can differ between dextran sodium sulfate preparations of the same molecular weight range. Dig Dis Sci. 2012 Feb;57(2):327-34. doi: 10.1007/s10620-011-1881-x. Epub 2011 Sep 8. PMID: 21901260.

38. Nagalingam NA, Kao JY, Young VB. Microbial ecology of the murine gut associated with the development of dextran sodium sulfate-induced colitis. Inflamm Bowel Dis. 2011 Apr;17(4):917-26. doi: 10.1002/ibd.21462. Epub 2010 Nov 8. PMID: 21391286; PMCID: PMC3058753.

39. Zhang Y, Ji W, Qin H, Chen Z, Zhou Y, Zhou Z, Wang J, Wang K. Astragalus polysaccharides alleviate DSS-induced ulcerative colitis in mice by restoring SCFA production and regulating Th17/Treg cell homeostasis in a microbiota-dependent manner. Carbohydr Polym. 2025 Feb 1;349(Pt A):122829. doi: 10.1016/j.carbpol.2024.122829. Epub 2024 Oct 3. PMID: 39643403.

40. Melgar S, Karlsson A, Michaëlsson E. Acute colitis induced by dextran sulfate sodium progresses to chronicity in C57BL/6 but not in BALB/c mice: correlation between symptoms and inflammation. Am J Physiol Gastrointest Liver Physiol. 2005 Jun;288(6):G1328-38. doi: 10.1152/ajpgi.00467.2004. Epub 2005 Jan 6. PMID: 15637179.

41. Arsenescu R, Arsenescu V, Zhong J, Nasser M, Melinte R, Dingle RW, Swanson H, de Villiers WJ. Role of the xenobiotic receptor in inflammatory bowel disease. Inflamm Bowel Dis. 2011 May;17(5):1149-62. doi: 10.1002/ibd.21463. Epub 2010 Sep 27. PMID: 20878756; PMCID: PMC3013235.

42. Vowinkel T, Kalogeris TJ, Mori M, Krieglstein CF, Granger DN. Impact of dextran sulfate sodium load on the severity of inflammation in experimental colitis. Dig Dis Sci. 2004 Apr;49(4):556-64. doi: 10.1023/b:ddas.0000026298.72088.f7. PMID: 15185857.

43. Shiomi Y, Nishiumi S, Ooi M, Hatano N, Shinohara M, Yoshie T, Kondo Y, Furumatsu K, Shiomi H, Kutsumi H, Azuma T, Yoshida M. GCMS-based metabolomic study in mice with colitis induced by dextran sulfate sodium. Inflamm Bowel Dis. 2011 Nov;17(11):2261-74. doi: 10.1002/ibd.21616. Epub 2011 Feb 1. PMID: 21287666.

44. Okayasu I, Yamada M, Mikami T, Yoshida T, Kanno J, Ohkusa T. Dysplasia and carcinoma development in a repeated dextran sulfate sodium-induced colitis model. J Gastroenterol Hepatol. 2002 Oct;17(10):1078-83. doi: 10.1046/j.1440-1746.2002.02853.x. PMID: 12201867.

45. Wurbel MA, McIntire MG, Dwyer P, Fiebiger E. CCL25/CCR9 interactions regulate large intestinal inflammation in a murine model of acute colitis. PLoS One. 2011 Jan 25;6(1):e16442. doi: 10.1371/journal.pone.0016442. PMID: 21283540; PMCID: PMC3026821.

46. Stevceva L, Pavli P, Husband A, Matthaei KI, Young IG, Doe WF. Eosinophilia is attenuated in experimental colitis induced in IL-5 deficient mice. Genes Immun. 2000 Feb;1(3):213-8. doi: 10.1038/sj.gene.6363654. PMID: 11196714.

47. Khor TO, Huang MT, Kwon KH, Chan JY, Reddy BS, Kong AN. Nrf2-deficient mice have an increased susceptibility to dextran sulfate sodium-induced colitis. Cancer Res. 2006 Dec 15;66(24):11580-4. doi: 10.1158/0008-5472.CAN-06-3562. PMID: 17178849.

48. Kumar G K, Dhamotharan R, Kulkarni NM, Honnegowda S, Murugesan S. Embelin ameliorates dextran sodium sulfate-induced colitis in mice. Int Immunopharmacol. 2011 Jun;11(6):724-31. doi: 10.1016/j.intimp.2011.01.022. Epub 2011 Feb 3. PMID: 21296695.

49. Murthy SN, Cooper HS, Shim H, Shah RS, Ibrahim SA, Sedergran DJ. Treatment of dextran sulfate sodium-induced murine colitis by intracolonic cyclosporin. Dig Dis Sci. 1993 Sep;38(9):1722-34. doi: 10.1007/BF01303184. PMID: 8359087.

50. Hirono I, Kuhara K, Hosaka S, Tomizawa S, Golberg L. Induction of intestinal tumors in rats by dextran sulfate sodium. J Natl Cancer Inst. 1981 Mar;66(3):579-83. PMID: 6162992.

51. Gaudio E, Taddei G, Vetuschi A, Sferra R, Frieri G, Ricciardi G, Caprilli R. Dextran sulfate sodium (DSS) colitis in rats: clinical, structural, and ultrastructural aspects. Dig Dis Sci. 1999 Jul;44(7):1458-75. doi: 10.1023/a:1026620322859. PMID: 10489934.

52. Zheng P, Niu FL, Liu WZ, Shi Y, Lu LG. Anti-inflammatory mechanism of oxymatrine in dextran sulfate sodium-induced colitis of rats. World J Gastroenterol. 2005 Aug 21;11(31):4912-5. doi: 10.3748/wjg.v11.i31.4912. PMID: 16097071; PMCID: PMC4398749.

53. Mallon PT, Mckenna M, Kirk SJ, Gardiner KR (2006) Dextran sulfate sodium (DSS) induced colitis reduces mucosal barrier function in Sprague-Dawley rats. Canadian Digestive Diseases Week (CDDW) February 24th–February 27th, 2006 ed. Banff, Alberta, Canadian Association of Gastroenterology

54. Schreiber O, Petersson J, Phillipson M, Perry M, Roos S, Holm L. Lactobacillus reuteri prevents colitis by reducing P-selectin-associated leukocyte- and platelet-endothelial cell interactions. Am J Physiol Gastrointest Liver Physiol. 2009 Mar;296(3):G534-42. doi: 10.1152/ajpgi.90470.2008. Epub 2009 Jan 15. PMID: 19147805.

55. Dicksved J, Schreiber O, Willing B, Petersson J, Rang S, Phillipson M, Holm L, Roos S. Lactobacillus reuteri maintains a functional mucosal barrier during DSS treatment despite mucus layer dysfunction. PLoS One. 2012;7(9):e46399. doi: 10.1371/journal.pone.0046399. Epub 2012 Sep 27. PMID: 23029509; PMCID: PMC3459901.

56. Petersson J, Schreiber O, Steege A, Patzak A, Hellsten A, Phillipson M, Holm L. eNOS involved in colitis-induced mucosal blood flow increase. Am J Physiol Gastrointest Liver Physiol. 2007 Dec;293(6):G1281-7. doi: 10.1152/ajpgi.00357.2007. Epub 2007 Oct 18. PMID: 17947450.

57. Vasina V, Broccoli M, Ursino MG, Canistro D, Valgimigli L, Soleti A, Paolini M, De Ponti F. Non-peptidyl low molecular weight radical scavenger IAC attenuates DSS-induced colitis in rats. World J Gastroenterol. 2010 Aug 7;16(29):3642-50. doi: 10.3748/wjg.v16.i29.3642. PMID: 20677336; PMCID: PMC2915424.

58. Tamaru T, Kobayashi H, Kishimoto S, Kajiyama G, Shimamoto F, Brown WR. Histochemical study of colonic cancer in experimental colitis of rats. Dig Dis Sci. 1993 Mar;38(3):529-37. doi: 10.1007/BF01316510. PMID: 7680303.

59. Chiba T. [Cell kinetics of carcinoma originating from rat colitis induced by dextran sulphate sodium]. Nihon Shokakibyo Gakkai Zasshi. 1993 Apr;90(4):774-81. Japanese. PMID: 8492469.

60. Breider MA, Eppinger M, Gough A. Intercellular adhesion molecule-1 expression in dextran sodium sulfate-induced colitis in rats. Vet Pathol. 1997 Nov;34(6):598-604. doi: 10.1177/030098589703400608. PMID: 9396141.

61. Hori Y, Hoshino J, Yamazaki C, Sekiguchi T, Miyauchi S, Horie K. Effects of chondroitin sulfate on colitis induced by dextran sulfate sodium in rats. Jpn J Pharmacol. 2001 Feb;85(2):155-60. doi: 10.1254/jjp.85.155. PMID: 11286397.

62. Aoi Y, Terashima S, Ogura M, Nishio H, Kato S, Takeuchi K. Roles of nitric oxide (NO) and NO synthases in healing of dextran sulfate sodium-induced rat colitis. J Physiol Pharmacol. 2008 Jun;59(2):315-36. PMID: 18622048.

63. Daddaoua A, Puerta V, Zarzuelo A, Suárez MD, Sánchez de Medina F, Martínez-Augustin O. Bovine glycomacropeptide is anti-inflammatory in rats with hapten-induced colitis. J Nutr. 2005 May;135(5):1164-70. doi: 10.1093/jn/135.5.1164. PMID: 15867298.

64. Yamada M, Ohkusa T, Okayasu I. Occurrence of dysplasia and adenocarcinoma after experimental chronic ulcerative colitis in hamsters induced by dextran sulphate sodium. Gut. 1992 Nov;33(11):1521-7. doi: 10.1136/gut.33.11.1521. PMID: 1333439; PMCID: PMC1379539.

65. Karlsson A, Jägervall A, Pettersson M, Andersson AK, Gillberg PG, Melgar S. Dextran sulphate sodium induces acute colitis and alters hepatic function in hamsters. Int Immunopharmacol. 2008 Jan;8(1):20-7. doi: 10.1016/j.intimp.2007.10.007. Epub 2007 Oct 29. PMID: 18068096.

66. Iwanaga T, Hoshi O, Han H, Fujita T. Morphological analysis of acute ulcerative colitis experimentally induced by dextran sulfate sodium in the guinea pig: some possible mechanisms of cecal ulceration. J Gastroenterol. 1994 Aug;29(4):430-8. doi: 10.1007/BF02361239. PMID: 7951852.

67. Leonardi I, Nicholls F, Atrott K, Cee A, Tewes B, Greinwald R, Rogler G, Frey-Wagner I. Oral administration of dextran sodium sulphate induces a caecum-localized colitis in rabbits. Int J Exp Pathol. 2015 Jun;96(3):151-62. doi: 10.1111/iep.12117. Epub 2015 Feb 26. PMID: 25716348; PMCID: PMC4545426.

68. Zou X, Ji J, Wang J, Qu H, Shu DM, Guo FY, Luo CL. Dextran sulphate sodium (DSS) causes intestinal histopathology and inflammatory changes consistent with increased gut leakiness in chickens. Br Poult Sci. 2018 Apr;59(2):166-172. doi: 10.1080/00071668.2017.1418498. Epub 2018 Jan 11. PMID: 29262695.

69. Young D, Ibuki M, Nakamori T, Fan M, Mine Y. Soy-derived di- and tripeptides alleviate colon and ileum inflammation in pigs with dextran sodium sulfate-induced colitis. J Nutr. 2012 Feb;142(2):363-8. doi: 10.3945/jn.111.149104. Epub 2011 Dec 21. PMID: 22190029.