Can Ruminococcus gnavus utilise mucin as carbon source? Identify papers where this was experimentally checked.

Yes, Ruminococcus gnavus can utilize mucin as a sole carbon source, as experimentally demonstrated in multiple studies using growth assays with purified porcine gastric mucin, though this capability is strain-dependent—strains possessing the complete Nan cluster and intramolecular trans-sialidase (such as ATCC 29149 and ATCC 35913) can degrade mucin, while strains lacking this enzymatic machinery (such as E1) cannot.

Abstract

This systematic review of 21 sources provides strong experimental evidence that Ruminococcus gnavus can utilize mucin as a sole carbon source, though this capability is strain-dependent. Multiple studies directly tested growth on purified porcine gastric mucin, consistently demonstrating that strains ATCC 29149 and ATCC 35913 can grow on mucin , while strain E1 cannot . The most comprehensive strain analysis tested 12 clinical isolates and found that 11 could grow on purified porcine gastric mucin . The molecular basis for this strain variation lies in the presence or absence of specific enzymatic machinery, particularly the complete Nan cluster and an intramolecular trans-sialidase (IT-sialidase) that releases the unique product 2,7-anhydro-Neu5Ac from mucin glycans . Additionally, a GH98 enzyme specific for blood group A antigens enables access to underlying glycan chains . In vivo validation using gnotobiotic mice confirmed that these enzymatic systems are essential for colonization of the mucus layer, with wild-type strains outcompeting nan deletion mutants .

The evidence conclusively demonstrates that R. gnavus possesses genuine mucin-degrading capability when equipped with the appropriate enzymatic machinery, producing propanol and propionate as major metabolic end products . This capability has clinical relevance, as R. gnavus is increased in inflammatory bowel disease patients and its IT-sialidases are more prevalent in IBD metagenomes . The strain-specific nature of mucin utilization—rather than representing conflicting findings—reflects genuine biological diversity within the species that may influence colonization success and disease associations in different gut environments.

Paper search

We performed a semantic search using the query "Can Ruminococcus gnavus utilise mucin as carbon source? Identify papers where this was experimentally checked." across over 138 million academic papers from the Elicit search engine, which includes all of Semantic Scholar and OpenAlex.

We retrieved the 497 papers most relevant to the query.

Screening

We screened in sources that met these criteria:

- **Target Bacterial Species**: Does this study investigate Ruminococcus gnavus specifically (either as the sole focus or as part of a multi-species study that includes R. gnavus)?
- **Experimental Mucin Testing**: Does this study include direct experimental testing of R. gnavus growth or metabolic activity on mucin-containing media or mucin as a carbon source?
- **Measurable Mucin Utilization Outcomes**: Does this study report measurable outcomes related to mucin utilization (such as bacterial growth, mucin degradation, enzymatic activity, metabolic products, or gene expression related to mucin metabolism)?

- **Controlled Laboratory Study**: Is this an in vitro laboratory study with controlled conditions using pure cultures, co-cultures, or defined microbial communities containing R. gnavus?
- **Authentic Mucin Substrates**: Does this study use authentic mucin substrates (such as purified mucin, mucin glycoproteins, or mucin-like substrates) as carbon sources?
- **Methodological Completeness**: Does this study provide sufficient methodological detail and complete results (i.e., is it a full research article rather than a conference abstract, preliminary report, or study lacking adequate methodological information)?
- **Mucin Utilization Focus**: Does this study focus on bacterial mucin utilization/consumption rather than mucin synthesis or production by host cells?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Data extraction

We asked a large language model to extract each data column below from each paper. We gave the model the extraction instructions shown below for each column.

- **R. gnavus Strain**:

  Extract the specific R. gnavus strain(s) tested including: - Strain designation (e.g., ATCC 29149, E1, VI-268) - Source/origin if mentioned - Any strain characteristics relevant to mucin utilization

- **Experimental Methods**:

  Extract all experimental approaches used to test mucin utilization including: - Growth assays (sole carbon source experiments) - Enzyme activity assays - Transcriptomic/genomic analyses - Metabolic profiling - Co-culture experiments - In vivo studies (gnotobiotic mice, etc.) - Any controls used

- **Mucin Substrate**:

  Extract details about the mucin used as substrate including: - Type/source (e.g., hog gastric mucin, human colonic mucin) - Preparation method - Concentration used - Any modifications or purification steps - Specific mucin components tested (oligosaccharides, glycans)

- **Mucin Utilization Results**:

  Extract specific findings about mucin utilization including: - Whether growth occurred on mucin as sole carbon source (yes/no/partial) - Quantitative measures (% hexose release, growth rates, OD values) - Comparison between strains if multiple tested - Time course of utilization - Any strain-specific differences noted

- **Enzymatic Mechanisms**:

  Extract information about enzymes and pathways involved in mucin degradation including: - Specific enzymes identified (sialidases, fucosidases, glycosidases) - Enzyme families (GH33, GH29, GH95, etc.) - Novel enzymatic activities (e.g., intramolecular trans-sialidases) - Enzyme location (extracellular, cell-bound) - Gene clusters involved (nan cluster, etc.)

- **Metabolic Products**:

  Extract metabolic end products and intermediates from mucin utilization including: - End products (propionate, propanol, acetate, etc.) - Intermediate compounds (2,7-anhydro-Neu5Ac, sialic acid) - Monosaccharides released - Quantitative measurements if provided - Metabolic pathway details

- **Experimental Conditions**:

  Extract key experimental parameters including: - Culture conditions (anaerobic/aerobic, temperature, pH) - Media composition - Incubation time - In vitro vs in vivo studies - Any co-factors or additives used - Growth phase analyzed

- **Key Findings**:

  Extract the main conclusions regarding R. gnavus mucin utilization including: - Overall conclusion about utilization capability - Functional significance in gut environment - Relevance to health/disease - Novel discoveries or mechanisms - Limitations or caveats noted by authors

Results

Characteristics of Included Studies

The systematic review identified 21 sources examining Ruminococcus gnavus and its relationship to mucin utilization. Studies varied considerably in their experimental approaches, with some providing direct growth assays using mucin as a sole carbon source while others focused on enzymatic characterization, genomic analysis, or cross-feeding interactions.

Study	Full text retrieved?	Study Type	R. gnavus Strains	Experimental Approach
Haiyang Wu et al., 2021	Yes	Primary study	ATCC 29149, E1	Growth assays, enzyme activity, transcriptomics, metabolic profiling
Haiyang Wu et al., 2022	No	Primary study	Not specified	Enzyme activity, transcriptomics, growth assays
E. Crost et al., 2013	Yes	Primary study	ATCC 29149, E1	Growth assays, transcriptomics, enzyme activity, metabolic profiling
E. Crost et al., 2016	Yes	Primary study	ATCC 29149, ATCC 35913, E1	Growth assays, transcriptomics, genomic sequencing
E. Crost et al., 2018	Yes	Primary study	ATCC 29149	Growth assays, transcriptomics, co-culture experiments
C. Png et al., 2010	No	Primary study	Not specified	Growth assays, real-time PCR, co-culture experiments

Study	Full text retrieved?	Study Type	R. gnavus Strains	Experimental Approach
Andrew Bell et al., 2019	Yes	Primary study	ATCC 29149, ATCC 35913, E1	Growth assays, enzyme activity, transcriptomics, gnotobiotic mice
K. Kim et al., 2023	No	Primary study	Not specified	Growth kinetics, multi-omics, in vivo experiments
Saori Kashiwagi et al., 2024	No	Primary study	Not specified	Growth kinetics, metabolic profiling, co-culture experiments
Andrew Bell et al., 2019a	No	Thesis/Review	Not specified	Enzyme activity, gnotobiotic mice, simulated colon model
O. Sokolovskaya et al., 2024	Yes	Primary study	ATCC 29149, RJX1126, RJX1128, 12 total isolates	Growth assays, genomic analyses
L. Tailford et al., 2015	Yes	Primary study	ATCC 29149, E1	Growth assays, enzyme activity, metagenome analysis
C. Png et al., 2009	No	Thesis	Not specified	In vitro degradation assay, in vivo mouse study
L. Hoskins et al., 1992	No	Primary study	Not mentioned (R. torques)	Enzyme activity, growth assays
C. Owen et al., 2017	Yes	Primary study	ATCC 29149, E1	Binding assays, crystallography, immunofluorescence
Janiece Glover et al., 2022	Yes	Primary study	Not specified	Growth assays (other species), genomic analysis
J. Glover et al., 2022	Yes	Primary study	Not specified	Growth assays (other species), genomic analysis
E. Thursby et al., 2016	No	Thesis	Not specified	In vitro growth assays, gnotobiotic mice
L. Hoskins et al., 1985	No	Primary study	Not mentioned	Enzyme activity, co-culture experiments

Study	Full text retrieved?	Study Type	R. gnavus Strains	Experimental Approach
Saori Kashiwagi et al., 2025	No	Conference abstract	Not specified	Growth assays, transcriptomics, metabolic profiling
Saori Kashiwagi et al., 2025a	No	Conference abstract	Not specified	Co-culture experiments, gnotobiotic mice

Of the 21 sources, 9 had full text available for detailed extraction. Two studies (L. Hoskins et al., 1985 and L. Hoskins et al., 1992) focused on Ruminococcus torques rather than R. gnavus specifically . The Glover et al. studies provided genomic characterization but did not include experimental growth data specifically for R. gnavus .

Direct Evidence for Mucin Utilization as Sole Carbon Source

Multiple studies directly tested whether R. gnavus strains could grow on mucin as a sole carbon source. The results consistently demonstrate strain-specific variation in this capability.

Study	Strain	Growth on Mucin as Sole Carbon Source	Quantitative Data	Key Conditions
E. Crost et al., 2013	ATCC 29149	Yes	1.5-hour lag period	Anaerobic, porcine gastric mucin
E. Crost et al., 2013	E1	No	Unable to grow	Anaerobic, porcine gastric mucin
E. Crost et al., 2016	ATCC 29149	Yes	Lag phase <2 hours	Anaerobic, 44 hours incubation
E. Crost et al., 2016	ATCC 35913	Yes	Identical max OD to ATCC 29149	Anaerobic, 44 hours incubation
E. Crost et al., 2016	E1	No	Unable to grow	Anaerobic
Haiyang Wu et al., 2021	ATCC 29149	Yes	Cell density increase at 48 hours	Anaerobic, 37℃
Haiyang Wu et al., 2021	E1	Partial (requires RgGH98)	Growth only with pretreated mucin	Anaerobic, 37℃
Andrew Bell et al., 2019	Wild-type	Yes	Nan cluster essential for colonization	In vitro and gnotobiotic mice
Andrew Bell et al., 2019	nan mutant	Impaired	Reduced mucus layer colonization	Gnotobiotic mice
O. Sokolovskaya et al., 2024	11 of 12 strains	Yes	2-3 doublings over background	Anaerobic, 1% pPGM
O. Sokolovskaya et al., 2024	RJX1126	No	Unable to grow on pPGM	Anaerobic
L. Tailford et al., 2015	ATCC 29149	Yes	Complete Nan cluster required	Not specified

Study	Strain	Growth on Mucin as Sole Carbon Source	Quantitative Data	Key Conditions
L. Tailford et al., 2015	E1	No	Lacks sialidase and Nan cluster	Not specified

The collective evidence demonstrates that R. gnavus can utilize mucin as a sole carbon source, but this capability is strain-dependent . The ATCC 29149 and ATCC 35913 strains consistently showed mucin-degrading capability across multiple studies , while the E1 strain uniformly failed to grow on mucin unless it was pre-treated with specific enzymes . O. Sokolovskaya et al. (2024) provided the most comprehensive strain analysis, testing 12 clinical isolates and finding that all but one (RJX1126) could grow on purified porcine gastric mucin .

Mucin Substrates Used in Experimental Studies

Study	Mucin Type/Source	Concentration	Preparation Details
E. Crost et al., 2013	Purified porcine gastric mucin (pPGM)	Not specified	Obtained as previously described
E. Crost et al., 2016	Type III pig gastric mucin, pPGM	Not specified	Purified
E. Crost et al., 2018	Type III PGM, pPGM	1% w/v	Prepared per Gunning et al., 2013
Haiyang Wu et al., 2021	Purified pig gastric mucin	10 mg/mL	Incubated with RgGH98
C. Png et al., 2010	Human secretory mucin (MUC2)	Not specified	Purified
O. Sokolovskaya et al., 2024	Porcine gastric mucin type III	1% w/v	Dissolved in PBS, ethanol sterilized, dialyzed
C. Owen et al., 2017	pPGM, mouse Muc2, human LS174T MUC2	10 µg/mL	Ultracentrifugation, dialysis
Saori Kashiwagi et al., 2024	PGM, ileal and colonic mucus from germ-free mice	Not specified	Supplemented M9 minimal media
Janiece Glover et al., 2022	Porcine intestinal mucus	1 mg/mL	Not specified

Most studies employed porcine gastric mucin at concentrations of 1% (w/v) or 10 mg/mL . Two studies specifically used human MUC2 , providing more clinically relevant substrate validation.

Enzymatic Mechanisms Underlying Mucin Utilization

The ability of R. gnavus to utilize mucin depends on specific enzymatic machinery, with notable variation between strains.

Enzyme/Cluster	Function	Key Finding	Study
GH33 IT-sialidase (RgNanH)	Releases 2,7-anhydro-Neu5Ac from α2-3-linked sialic acid	Novel trans-sialidase activity distinct from conventional sialidases	L. Tailford et al., 2015
GH98 (RgGH98)	Cleaves blood group A tetrasaccharide type II	Specific for blood group A antigens; part of 10-gene operon	Haiyang Wu et al., 2021
GH29, GH95 fucosidases	Release fucose from mucin glycans	Upregulated on fucosylated substrates	E. Crost et al., 2013
Nan cluster	Sialic acid transport and metabolism	Essential for mucus layer colonization in vivo	Andrew Bell et al., 2019
RgNanOx oxidoreductase	Converts 2,7-anhydro-Neu5Ac to Neu5Ac	Novel enzyme in sialic acid pathway	Andrew Bell et al., 2019a
RgNanA aldolase	Cleaves Neu5Ac to ManNAc and pyruvate	Final step in sialic acid catabolism	Andrew Bell et al., 2019
RgSBP transporter	Specific uptake of 2,7-anhydro-Neu5Ac	Uniquely specific for 2,7-anhydro-Neu5Ac	Andrew Bell et al., 2019a
RgCBM40	Carbohydrate binding module for mucin adhesion	Novel bacterial mucus adhesin	C. Owen et al., 2017

The most significant enzymatic discovery is the intramolecular trans-sialidase (IT-sialidase), which releases 2,7-anhydro-Neu5Ac rather than conventional sialic acid from mucin glycans . This product is transported by a dedicated ABC transporter with unique specificity for 2,7-anhydro-Neu5Ac and subsequently converted to Neu5Ac by a novel oxidoreductase (RgNanOx) . The presence of the complete Nan cluster distinguishes mucin-degrading strains (ATCC 29149, ATCC 35913) from non-degrading strains (E1) .

The GH98 enzyme demonstrates specificity for blood group A antigens, enabling access to underlying mucin glycan chains . Pre-treatment of mucin with RgGH98 conferred the ability of non-mucin-degrading E1 strain to grow on the substrate , demonstrating the critical role of this enzyme in initiating mucin degradation.

Metabolic End Products from Mucin Utilization

Study	Intermediate Compounds	End Products	Pathway Details
E. Crost et al., 2013	2,7-anhydro-Neu5Ac, sialic acid	Propanol, propionate	Propanediol pathway; nan cluster genes
E. Crost et al., 2016	2,7-anhydro-Neu5Ac, Neu5Ac, GlcNAc-6-P	Not specified	Glycolytic pathway entry
E. Crost et al., 2018	Fucose, sialic acid	Propanol	Propane-1,2-diol pathway
Haiyang Wu et al., 2021	GlcNAc, BgAtri	Not specified	RgGH98-mediated cleavage
Andrew Bell et al., 2019	2,7-anhydro-Neu5Ac, Neu5Ac	ManNAc, pyruvate	Sialic acid aldolase pathway

Study	Intermediate Compounds	End Products	Pathway Details
L. Hoskins et al., 1992	Galactose, fucose, GlcNAc, GalNAc	Not specified	70-98% utilization by fecal bacteria

R. gnavus produces propanol and propionate as major end products when grown on mucin and fucosylated glycans . The unique 2,7-anhydro-Neu5Ac intermediate provides a competitive advantage, as this compound cannot be utilized by many other gut bacteria or pathogens .

In Vivo Validation Studies

Several studies extended in vitro findings to animal models:

Study	Model System	Key In Vivo Finding
Andrew Bell et al., 2019	Gnotobiotic mice	Wild-type outcompeted nan mutant in colonizing mucus layer
Andrew Bell et al., 2019a	Gnotobiotic mice	Nan cluster important for colonization and spatial location in mucus
C. Png et al., 2009	Antibiotic-treated C57BL/6 mice	R. gnavus feeding induced Paneth cell response but not colitis
E. Thursby et al., 2016	Gnotobiotic mice	R. gnavus remodeled mucin glycosylation
Saori Kashiwagi et al., 2025a	Germ-free IL10-/- mice	Dual colonization with AIEC potentiated colitis

Gnotobiotic mouse experiments confirmed that the nan cluster is essential for optimal colonization of the mucus layer . The wild-type strain significantly outcompeted nan deletion mutants in establishing residence within the mucus niche .

Relevance to Health and Disease

Multiple studies linked R. gnavus mucin utilization to inflammatory bowel disease (IBD):

- R. gnavus was increased >4-fold in macroscopically normal intestinal epithelium of both Crohn's disease and ulcerative colitis patients
- IT-sialidases are more prevalent in IBD metagenomes compared to healthy subjects
- R. gnavus remained unaffected by UC-like mucin glycosylation changes that impaired A. muciniphila growth
- Cross-feeding between R. gnavus and adherent-invasive E. coli (AIEC) enhanced growth and H2S production, potentially contributing to disease progression

The ability of R. gnavus to utilize mucin may provide ecological advantages in the inflamed gut environment while simultaneously contributing to dysbiosis through altered mucin availability for other commensals .

Synthesis

The evidence overwhelmingly supports that R. gnavus can utilize mucin as a carbon source, though this capability exhibits significant strain-level heterogeneity. The apparent contradiction between mucin-degrading and non-degrading strains within the same species is resolved by genomic analysis revealing that mucin utilization requires specific enzymatic machinery—particularly the complete Nan cluster and IT-sialidase—which is present in strains ATCC 29149 and ATCC 35913 but absent in strain E1 .

The mechanisms underlying this capability are now well-characterized. The IT-sialidase produces 2,7-anhydro-Neu5Ac, a unique sialic acid derivative that provides R. gnavus with a competitive nutritional advantage . This product is sequestered by a specific transporter and metabolized through a dedicated pathway involving the novel oxidoreductase RgNanOx . The GH98 enzyme additionally enables access to blood group A-containing mucin glycans , while fucosidases (GH29, GH95) release fucose for metabolism through the propanediol pathway .

Strain variation in mucin utilization reflects genuine biological diversity rather than methodological inconsistency. O. Sokolovskaya et al. (2024) demonstrated this conclusively by testing 12 clinical isolates and finding that 11 could grow on purified porcine gastric mucin, while one strain (RJX1126) could not . Importantly, this study also identified strains with "partial" sialic acid catabolism pathways representing the canonical Neu5Ac pathway, previously unreported in R. gnavus .

The functional significance of mucin utilization extends beyond simple carbon acquisition. In vivo experiments demonstrate that the nan cluster is essential for optimal colonization of the mucus layer , with wild-type strains significantly outcompeting nan mutants in gnotobiotic mice . This spatial adaptation may explain why R. gnavus is disproportionately represented in IBD patients , where altered mucin glycosylation patterns may favor species capable of flexible mucin degradation strategies .

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