

ISSN 1751-7311

OCTOBER 2010

VOLUME 4 NUMBER 10



# animal

AN INTERNATIONAL JOURNAL OF ANIMAL BIOSCIENCE



animal

CAMBRIDGE  
UNIVERSITY PRESS

# ANIMAL

## Editor-in-Chief

M. DOREAU, France

## Strategic Development Editor

J. OLDHAM, UK

## Reviews

K. SEJRSEN, Denmark

## Editorial Office

Email: [questions@animal-journal.eu](mailto:questions@animal-journal.eu)

N. MIRAUX (Editorial Assistant),

B. HILTON, F. FERGUSON and F. NORMAND

## Section (SE) and Deputy Section

### Editors (DSE)

J. WELLER (SE – Breeding and Genetics, Israel)

S. RODRIGUEZ-ZAS (DSE – Breeding and Genetics, USA)

R. DEWHURST (SE – Nutrition Ruminants, Ireland)

P. MOUGHAN (SE – Nutrition Nonruminants, New Zealand)

D. TORRALLARDONA (DSE – Nutrition Nonruminants, Spain)

I. ORTIGUES-MARTY (DSE – Nutrition Ruminants, France)

R. HILL (SE – Physiology and Functional Biology of Systems, USA)

M. VESTERGAARD (DSE – Physiology and Functional Biology of Systems, Denmark)

S. EDWARDS (SE – Behaviour, Health and Welfare, UK)

M. COCKRAM (DSE – Behaviour, Health and Welfare, Canada)

A. BERNUES (SE – Farming Systems and Environment, Spain)

M. GAULY (DSE – Farming Systems and Environment, Germany)

A. BALDI (SE – Product Quality, Human Health and Well-Being, Italy)

P. GUESNET (DSE – Product Quality, Human Health and Well-Being, France)

## Editors

### Breeding and Genetics:

Y. DA (USA), H. KHATIB (USA),

D. J. DE KONING (UK), C. KÜHN (Germany),

A. MALAU-ADULI (Australia),

Y. SOGIMOTO (Japan), J. SZYDA (Poland)

**Nutrition:** J. BRAMELD (UK), L. DOEPEL

(Canada), V. FIEVEZ (Belgium), W. GERRITS

(The Netherlands), H. LAPIERRE (Canada),

S. MACKENZIE (UK), W. MARTIN-ROSSET

(France), J. NEWBOLD (Belgium),

D. PACHECO (New Zealand), R. RAVINDRAN

(New Zealand), M. J. RANILLA (Spain),

N. SCOLLAN (UK), N. TROTIER (USA),

J. VAN MILGEN (France), A. VAN VUUREN

(The Netherlands), B. WILLIAMS (Australia)

### Physiology and Functional Biology of

**Systems:** J. A. ABECIA (Spain),

G. DAHL (USA), G. GONZALEZ MARISCAL

(Mexico), G. HAUSMAN (USA),

K. HOLTENIUS (Sweden), P. LACASSE

(Canada), D. MILLER (USA), G. VATZIAS

(Greece), P. WYNN (Australia), J. YANG (USA)

## Behaviour, Welfare and Health:

A. BOISSY (France), E. VON BORELL

(Germany), U. EMANUELSON (Sweden),

C. FOURICHON (France), H. JUUL-MADSEN

(Denmark), X. MANTECA (Spain),

B. NIELSEN (Denmark),

E. WATTRANG (Sweden)

## Farming Systems and Environment:

A. ADESOGAN (USA), M. BONNEAU (France),

H. CLARK (New Zealand), A. DUNCAN

(Ethiopia), N. MIRAGLIA (Italy), A. MOLONEY

(Ireland), H. POULSEN (Denmark),

A. PRIOLO (Italy), J. T. SORENSEN (Denmark)

## Product Quality, Human Health and

**Well-Being:** M. CAMPO (Spain),

I. GIVENS (UK), K. SHINGFIELD (Finland)

## Aims and Scope of the journal

*Animal* is a completely new entity that seeks to attract the best research in animal biology and animal systems from across the spectrum of the agricultural, biomedical, and environmental sciences; it is the central element in an exciting collaboration between the *British Society of Animal Science* (BSAS), the *Institut National de la Recherche Agronomique* (INRA) and the *European Association of Animal Production* (EAAP) and represents a merging of the three scientific journals: *Animal Science*; *Animal Research*; *Reproduction, Nutrition, Development*. *Animal* will publish original cutting-edge research, 'hot' topics and horizon-scanning reviews on animal-related aspects of the life sciences at the molecular, cellular, organ, whole animal and production system levels.

The main subject areas include: breeding and genetics; nutrition; physiology and functional biology of systems; behaviour, health and welfare; farming systems, environmental impact and climate change; product quality, human health and well-being. Animal models and papers dealing with the integration of research between these topics and their impact on the environment and people will be particularly welcome. The detailed scope of the journal can be found at [www.animal-journal.eu/scope.htm](http://www.animal-journal.eu/scope.htm)

## Submission of Manuscripts

All manuscripts must be submitted online via the website: <http://www.editorialmanager.com/animal/>

Please consult the full instructions for

authors at: [www.animal-journal.eu/](http://www.animal-journal.eu/instructions_to_authors.htm)

[instructions\\_to\\_authors.htm](http://www.animal-journal.eu/instructions_to_authors.htm)

## Subscriptions

*Animal* (ISSN 1751-7311) is published monthly. The subscription price for institutions of Volume 4 (2010) which includes electronic access and delivery by air is £640, €915 (US \$1340 in the USA, Canada and Mexico); the electronic only price for institutions is £551, €790 (US \$1160 in the USA, Canada and Mexico). Single parts are £58, €75 (US \$122 in the USA, Canada and Mexico), plus postage.

Orders, which must be accompanied by payment, may be sent to a bookseller, subscription agent or direct to the publisher: Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 8RU, UK; or in the USA,

Canada and Mexico: Cambridge University Press, Journals Fulfillment Department, 100 Brook Hill Drive, West Nyack, New York, 10994-2133. EU subscribers (outside the UK) who are not registered for VAT should add VAT at their country's rate. VAT registered subscribers should provide their VAT registration number. Japanese prices for institutions are available from Kinokuniya Company Ltd, P. O. Box 55, Chitose, Tokyo 156, Japan.

Copies of the journal for subscribers in the USA, Canada and Mexico are sent by air to New York to arrive with minimum delay. Periodicals postage paid at New York, NY, and at additional mailing offices. Postmaster: send address changes in the USA, Canada and Mexico to: *Animal*, Cambridge University Press, 100 Brook Hill Drive, West Nyack, New York 10994-2133. Claims for missing issues should be made immediately on receipt of the subsequent issue.

## Advertising

Advertising queries for all parts of the world *except* the USA, Canada and Mexico to the Journals Advertising Co-ordinator: Rebecca Curtis [ad\\_sales@cambridge.org](mailto:ad_sales@cambridge.org). Address enquiries in the USA, Mexico and Canada only to: [journals\\_advertising@cup.org](mailto:journals_advertising@cup.org)

## Copying

This journal is registered with the Copyright Clearance Centre, 222 Rosewood Drive, Danvers, MA 01923. USA.

Organizations in the USA who are also registered with C. C. C. may therefore copy material (beyond the limits permitted by sections 107 and 108 of U. S. Copyright law) subject to promotional or commercial purposes. Code 0266-4674/2010 \$16.00.

*ISI Tear Sheet Service*, 3501 Market Street, Philadelphia, PA 19104, USA is authorized to supply single copies of separate articles for private use only.

Organizations authorized by the Copyright Licensing Agency may also copy material subject to the usual conditions. *For all other use*, permission should be sought from Cambridge or the American Branch of Cambridge University Press.

## Internet Access

This journal is included in the Cambridge Journals Online Service which can be found at [www.journals.cambridge.org](http://www.journals.cambridge.org)

## Front cover images

Mountain scene photograph courtesy of Julian Casásús. Other images © INRA Picture Library.

This journal issue has been printed on FSC-certified paper and cover board. FSC is an independent, non-governmental, not-for-profit organization established to promote the responsible management of the World's forests. Please see [www.fsc.org](http://www.fsc.org) for information.

Printed in the UK by Bell & Bain Ltd., Glasgow.

© Animal Consortium 2010

# animal

AN INTERNATIONAL JOURNAL OF ANIMAL BIOSCIENCE



CAMBRIDGE

JOURNALS



# World's Poultry Science Journal

Published on behalf of the  
World's Poultry Science Association

**World's Poultry Science Journal**

is available online at  
[journals.cambridge.org/wps](http://journals.cambridge.org/wps)

**To subscribe contact  
Customer Services**

**in Cambridge:**

Phone +44 (0)1223 326070  
Fax +44 (0)1223 325150  
Email [journals@cambridge.org](mailto:journals@cambridge.org)

**in New York:**

Phone +1 (845) 353 7500  
Fax +1 (845) 353 4141  
Email  
[journals\\_subscriptions@cambridge.org](mailto:journals_subscriptions@cambridge.org)

**Editor**

Lucy Tucker, Waiti Hill Ltd, New Zealand

*World's Poultry Science Journal* provides authoritative reviews in poultry science and an international forum for the exchange and dissemination of information including research, education and industry organisation. Each issue includes poultry industry related news, regional reports on global developments in poultry, reports from specialist scientific working groups, book reviews, association news and a calendar of forthcoming events.

**NEW - Digital Archive!**

Access from the first issue in 1945 until 2003 online!  
For more information, email, quoting filler0709:  
In the USA, Canada and Mexico  
[USJournals@cambridge.org](mailto:USJournals@cambridge.org)  
Rest of the World [jnlsales@cambridge.org](mailto:jnlsales@cambridge.org)

**Free email alerts**

Keep up-to-date with new material –sign up at  
<http://journals.cambridge.org/alerts>

For free online content visit:  
<http://journals.cambridge.org/wps>



CAMBRIDGE  
UNIVERSITY PRESS