UNIVERSITY OF CAMBRIDGE

Le Bien-être des canards pendant la production de foie gras

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Préface et table des matières de la traduction française

Le présent rapport a fait l'objet d'une traduction partielle vers le français. Pour des raisons de lisibilité, les extraits traduits ont tous été placés en début de rapport. Ils se présentent comme suit :

A partir de la version anglaise du rapport, la numérotation est réinitialisée.

University of Cambridge

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Le 14 septembre 2015

Cette analyse de la littérature sur la production de foie gras de palmipèdes se concentre sur les implications que peut entraîner cette pratique d'élevage pour le bien-être des oiseaux. Cette étude se focalise sur les canards plutôt que sur les oies, car les premiers représentent plus de 97 % de la production de foie gras en France (18.600 tonnes en 2013) (Litt et Pé 2015). En 2012, la Belgique a produit environ 25 tonnes de foie gras, provenant à 92 % de canards (Service public fédéral, 2014).

La grande majorité des publications sur le foie gras dans des revues scientifiques a été réalisée par de chercheurs français de l'INRA (Institut National de Recherches Agricoles) et de l'ITAVI (Institut Technique de l'Aviculture), qui possèdent des centres dédiés à ce type de recherches. Nous sommes très reconnaissants des sources et des réponses qu'ont bien voulu nous fournir Dr. D. Guémené, de l'INRA, et Dr. J. Litt, de l'ITAVI.

En raison de la quantité réduite de la littérature scientifique et académique sur le bien-être des canards pendant la production de foie gras, nous avons également consulté des procès-verbaux, plus particulièrement des procès-verbaux relatifs aux biennales « Journées de la Recherche sur les Palmipèdes à Foie Gras », ainsi que des brochures techniques et des textes autonomes provenant de sources connues sur internet. Nous avons évité autant que possible l'utilisation de documents issus d'organismes agissant en faveur ou à l'encontre de la production de foie gras, ainsi que l'emploi de documents non fondés provenant de sources douteuses ou d'opinions personnelles.

Un grand nombre d'organisations mènent des campagnes contre la production de foie gras, et certaines ont publié à cet égard des rapports, des documentaires ou des présentations, qui sont disponibles en ligne. Parmi ces organisations se trouvent la British Columbia SPCA, Compassion in World Farming, GAIA (Groupe d'Action dans l'Intérêt des

Animaux), Global Action Network, Humane Society of the United States, L214 Ethique et Animaux, OneKind (anciennement Advocates for Animals), Viva!, World Animal Protection (anciennement World Society for the Protection of Animals), et d'autres encore. Des avis concis sont disponibles auprès de l'American Veterinary Medical Association (JA VMA 2014) et de la Canadian Veterinary Medical Association (Skippon 2013). Par ailleurs, de nombreux organismes réalisent également la promotion de la production et de la consommation de foie gras.

Nous tenons à remercier l'organisation belge GAIA pour son soutien dans la préparation et la réalisation de ce rapport de l'Université de Cambridge. Celui-ci se base sur les informations scientifiques et factuelles existantes, et son contenu est indépendant de toute source de financement.

Synthèse

Cette étude de la littérature scientifique sur la production de foie gras examine les implications que peut entraîner cette pratique d'élevage, plus particulièrement le gavage, pour le bien-être des canards. Si la production de foie gras est considérée comme une tradition gastronomique française de longue date, il convient de noter qu'historiquement, les oies étaient préférées aux canards. En 10 ans (de 2003 à 2013), la production nationale a augmenté de 10,7 %, et concerne à 97,6 % les canards. Le secteur français fait actuellement face à certains défis, comme l'obligation de recourir à des cages collectives à partir de janvier 2016, ainsi que des attentes plus grandes en matière de bien-être animal de la part des consommateurs. La transition en faveur des cages collectives a déjà été opérée en Belgique.

La pratique du gavage prive le canard de la maîtrise d'un aspect de sa vie, qui est crucial à sa survie : l'ingestion de nourriture adaptée en quantités adaptées. La perte de cette maîtrise engendre une très forte dégradation de son bien-être.

Effets sur la santé

Il existe peu de statistiques sur la mortalité chez les canards utilisés pour la production de foie gras. En 2013, la mortalité moyenne en France s'élevait à 2.2 % sur la période du gavage (Litt et Pé 2015). Le Comité scientifique de la santé et du bien-être des animaux (CSSBA) a attesté en 1998 la présence de déformations dans la posture debout et dans les déplacements, en raison de l'élargissement du foie engraissé et d'autres pathologies comme des fragilités osseuses et des lésions aux pattes. Plus récemment, Litt et collab. ont décrit l'élaboration (2015a) et l'application (2015c) d'une grille d'évaluation de l'état physique des canards mulards. Au fur et à mesure que les oiseaux passaient par les différents stades de la production, leur état se détériorait. Des blessures aux ailes, dont des fractures de l'humérus, étaient fréquentes, et se produisaient le plus souvent lors du ramassage, du transport vers l'abattoir et de l'accrochage. Les pododermatites, les brûlures du jarret, les lésions à la poitrine, les blessures dans la région du dos (principalement des griffures) et à l'œsophage (pseudo-jabot) ont été reprises parmi les éléments à prendre en compte pour évaluer le bien-être des canards.

Des études ont comparé, d'une part, l'ampleur de l'extravasation après stimulation nociceptive, et d'autre part, le processus du gavage ; mettant en lumière la présence d'œsophagite chez les canards gavés (Servière et collab. 2002, 2011). Cependant, il existe peu de données sur des observations post-mortem – que ce soit à l'œil nu ou au microscope – de la partie haute de l'appareil digestif, avant, pendant et à la fin du gavage. Le risque de lésions pourrait être plus élevé dans les logements collectifs puisque ceux-ci impliquent d'attraper, de manipuler et de maîtriser les oiseaux.

Le canard mulard n'est pas un animal migratoire et son foie n'atteint jamais un volume très étendu lorsqu'il est élevé normalement. Or, à la fin de la période de gavage, son foie présente une taille de 7 à 10 fois supérieure à la normale, pèse de 550 à 700 g et enregistre un taux de graisse de 55,8 %. La stéatose, ainsi que les autres modifications de l'état du foie résultant du nourrissage pour la production de foie gras et le gavage en particulier, sont d'ordre pathologique et peuvent nuire à la survie du canard. La capacité moindre du foie à détoxifier, comme l'indiquent une clairance de la BSP plus lente, la demi-vie plus longue de la BSP, ainsi que l'augmentation des enzymes du foie à la fin de la période de gavage, sont autant de preuves de l'existence d'une pathologie clinique.

Effets directs du gavage

Les canards montrent une série de réactions comportementales au gavage, telles qu'une agitation accrue pendant les 3 premiers jours, suivie par des périodes de repos plus longues, des battements d'ailes, des secouements de la tête, des périodes plus courtes de repos de la tête, des comportements réduits de nettoyage et de lissage des plumes, ainsi qu'une mobilité réduite. En raison de la grande quantité de nourriture administrée de force, les canards passent une bonne partie de leur temps à haleter afin d'évacuer le surplus de chaleur généré par le processus de digestion. Ce stress thermique les rend très sensibles à la chaleur de leur environnement, ce qui accentue leur inconfort. La description et l'interprétation des modifications du comportement des oiseaux en période de gavage et dans une perspective de bien-être animal représentent des aspects qui sont absents de nombreuses études.

Faure et collab. (2001) ont comparé d'un côté le comportement montré par des canards gavés à l'approche du gaveur, et de l'autre leur comportement à l'approche d'une personne neutre. Le critère choisi (la distance à partir de laquelle l'oiseau montre un mouvement d'évitement dans sa cage individuelle) et l'effet de confusion lié à la reconnaissance de la personne du gaveur rendent scientifiquement invalide la conclusion selon laquelle l'acte du gavage n'est pas aversif pour les canards. Des résultats valables pourraient être obtenus en répétant l'expérience, mais en utilisant un meilleur critère ainsi que deux personnes connues l'une comme l'autre des canards – l'une exécutant l'acte du gavage et l'autre pas.

Des études ont utilisé la corticostérone et l'axe HPA en tant que marqueurs de stress chez les canards pendant le gavage, mais leurs méthodes expérimentales diffèrent beaucoup. Par ailleurs, la nourriture peut empêcher une hausse des glucocorticoïdes tandis que l'activité peut l'accentuer, ce qui amène d'autres facteurs de complication. Les résultats obtenus par Guémené et collab. (2001, 2006a) et Flament et collab. (2012) sur les niveaux de corticostérone avant et après le gavage ne coïncident pas avec ceux relevés par Mirabito et collab. (2002c) ainsi que Mohammed et collab. (2014). Notre conclusion est donc que les niveaux de corticostérone dans le sang représentent un indicateur peu fiable du bien-être des canards mulards dans les études existantes.

Des tentatives de stimulation de la suralimentation spontanée des oies ont vu le jour, en manipulant la longueur de la journée et l'alimentation – généralement par une période de restriction suivie par un nourrissage à volonté (Guy et collab. 2013). Il semblerait que, sous certaines conditions d'alimentation et de photopériode, les oies soient capables de développer, sans nourrissage forcé, une stéatose hépatique, et ainsi de permettre une production de foie gras sans gavage. Cependant, cette méthode alternative présente actuellement un grand impact négatif sur l'environnement, et certains consommateurs n'apprécient pas le produit.

Par ailleurs, un risque pour la santé humaine peut être associé à la consommation de foie gras de canards ou d'oies. La protéine amyloïde contenue dans celui-ci pourrait accélérer le développement de l'amylose dans une partie de la population humaine.

Hébergement

L'hébergement de canards dans des cages à peine plus larges que leur corps, et laissant leur cou et leur tête saillants pour permettre l'acte du gavage, nuit fortement à leur bien-être. Dès janvier 2016, les cages collectives pour la production de foie gras seront illégales en France, et devront être remplacées par de l'hébergement en groupes. En Belgique, l'hébergement collectif est déjà obligatoire. Cette forme d'élevage permet les interactions sociales entre les oiseaux, et leur fournit plus d'espace en tant que groupe. Par rapport aux cages individuelles, l'hébergement collectif entraîne une baisse du poids du foie, une augmentation de la durée nécessaire pour l'acte du gavage, et une augmentation du volume d'eau utilisée pour le nettoyage. Autres différences enregistrées : une légère augmentation du poids du magret (Litt 2010, Mirabito et collab. 2002a), une hausse des troubles hépatiques à l'abattage, moins d'hématomes mais plus d'écorchures sur la carcasse.

Selon Guémené et collab. (2002, 2006b), la capture et l'immobilisation des oiseaux élevés en groupe pour l'acte du gavage peuvent être une cause de stress répété. Une méthode de contention des oiseaux a été développée afin d'empêcher leurs comportements de fuite, de lutte ou de retrait au fond de la cage, qui rendent difficile l'acte du gavage. Les oiseaux hébergés en cages collectives courent un plus grand risque d'être blessés par la manipulation, de se trouver coincés dans le mécanisme de contention de la cage, ou d'être confinés sur une longue période. La plupart des cages sont de petite taille, présentent une surface par animal de 1200 cm^2 à 1300 cm^2, et un sol en treillis métallique ou plastique. Malgré les recommandations du Conseil de l'Europe (1999), elles ne contiennent ni litière, ni aire de repos, ni matériel de nidification. Ces manquements peuvent entraîner une aggravation des dermatites de contact, qui sont déjà présentes au début et à la période de croissance de la production de foie gras (Litt et collab. 2015c), ainsi qu'affecter le confort, les comportements d'exploration et de recherche de nourriture, et les interactions sociales des oiseaux.

Les canards ont besoin d'un point d'eau, par exemple via un abreuvoir ou une bassine, afin d'entretenir leur plumage et leur corps ainsi que pour la thermorégulation. Certains pays imposent légalement la possibilité pour les canards d'immerger leur tête entièrement, de laisser l'eau leur recouvrir la tête et remplir leur bec pour qu'ils puissent ensuite asperger tout leur corps sans difficulté. Les cages utilisées pour le gavage des canards comportent des abreuvoirs, mais les dimensions minimales que ceux-ci devraient présenter n'ont jamais été établies et à notre connaissance, il n'existe aucune étude sur l'utilisation d'abreuvoirs ou sur la propreté de l'eau et le comportement des canards gavés en relation avec ces abreuvoirs. Il semblerait par ailleurs que cet équipement n'est pas toujours prévu pour les canards lors des deux premiers stades de la production de foie gras.

Comportement

Les canards mulards sont l'espèce la plus concernée par la production de foie gras, et certains individus sont considérés comme particulièrement craintifs, nerveux et hyper-réactifs – on parle de « nervosisme ». Ils manifestent un comportement de panique et de fuite à l'approche d'êtres humains et sont généralement décrits comme « sensibles à leur environnement » (Guémené et collab. 2002, Guémené et collab. 2006b, Laborde et Voisin 2013). Dans les petites cages individuelles, la peur de l'homme doit être présente chez les canards, mais leur incapacité à se mouvoir résout le problème pour les gaveurs. L'abandon du système en cages individuelles au profit de l'hébergement en groupe semble avoir placé le problème du nervosisme des canards à l'avant plan. Les mulards manifestent des réactions claires de panique et de peur des humains, et se montrent plus sensibles au stress social (isolement hors d'un groupe d'autres canards) que les deux espèces parentes (Arnaud et collab. 2008). Ils présentent également des niveaux basaux plus élevés de corticostérone que ces dernières.

A l'aide de questionnaires détaillés et d'enquêtes par téléphone auprès de gaveurs et d'éleveurs de canards, des aspects liés à des pratiques d'élevage précédant la période de gavage ont été étudiés au regard de leur impact sur le comportement des canards pendant le gavage (Laborde et Voisin 2013). De toute évidence, le bien-être des canards réactifs, nerveux et craintifs est moindre que celui des canards calmes, puisqu'ils sont moins capables de s'accommoder des changements d'environnement et de la présence de personnes humaines.

Autres considérations de bien-être

Il a été prouvé que les interactions négatives entre des individus humains et des animaux accentuent la peur et le stress chez les animaux (Hemsworth 2007). Dans le cas de la production de foie gras, la relation entre le gaveur et le canard gavé a fait l'objet de peu d'attention, mais les réactions observées – des comportements de lutte et de fuite – sont typiques des animaux d'élevage sujets à des procédures de routine qu'ils ressentent comme douloureuses, stressantes et désagréables (Vinuela-Fernandez et collab. 2011).

Les quatre principes de Bien-être et les 12 critères proposés par le projet Welfare Quality® (Blokhuis et collab. 2010) comportent des directives générales sur les besoins de l'animal et comment les respecter. Sur la base des informations dont nous disposons, et contrairement aux objectifs fixés par la Fédération européenne du foie gras dans sa charte, seuls trois des douze critères et pas un seul principe de bien-être ne sont respectés dans les systèmes actuels de production de foie gras. Les canards et les oies concernés par cette production sont les seuls animaux d'élevage qui sont privés des mécanismes biologiques fondamentaux de régulation de leur alimentation.

L'objectif premier de cette étude est de déterminer les problèmes de bien-être qui se posent lors de la dernière étape de la production de foie gras, c'est à dire la phase de gavage des canards. Cependant, de tels problèmes ont également été identifiés lors des deux premières phases, au démarrage et pendant la croissance. Ils concernent l'apparition précoce, fréquente et rapide de pododermatites, de brûlures du jarret, d'ampoules du bréchet, mais aussi la peur de l'homme et une grande sensibilité à l'environnement, et l'absence d'un accès à un point d'eau pour la baignade ou du moins l'immersion de la tête.

Introduction

En 1998, le Comité scientifique sur la santé et le bien-être animal (SCAHAW) a publié pour la Commission européenne un rapport sur le bien-être des canards et des oies lors de la production de foie gras (SCAHAW 1998). Sa conclusion était que « le gavage est préjudiciable au bien-être des oiseaux ». Plusieurs chercheurs français qui ont étudié plusieurs paramètres pendant la phase de gavage ont rejeté la conclusion du Comité scientifique (Guémené et Guy 2004).

Dans l'Union européenne, les pays producteurs de foie gras sont la France, la Belgique, la Bulgarie, la Hongrie et l'Espagne (Litt et Pé 2015). Un historique de la production de foie gras en France est fourni par Guémené et Guy (2004) et dans le rapport du SCAHAW (1998). La loi française (Code rural, article L654-27-1) établit que « le foie gras fait partie du patrimoine culturel et gastronomique protégé en France. » Cependant, la longue tradition française était d'utiliser des oies, et non des canards. La pratique a donc été modifiée dans une grande mesure.

La Fédération européenne des producteurs du foie gras a vu le jour en 2008 et se compose de membres émanant des cinq pays producteurs européens. Son site internet fournit des chiffres de production de foie gras, et vise à maintenir et protéger cette industrie (voir http://www.eurofoiegras.com). Pour ce qui est du foie gras en Belgique et plus généralement en Europe, un rapport scientifique belge a été récemment publié à la demande du Conseil belge du Bien-être animal (SPF Santé publique 2014). Ce rapport belge examine deux aspects principaux : 1) le caractère éthique de la pratique du gavage au regard des devoirs de la société envers les animaux et 2) le bien-être des canards gavés, plus particulièrement lorsqu'ils atteignent un état d'obésité à la fin du gavage.

Nous n'avons pas trouvé d'éléments d'information fiables concernant les méthodes de production dans d'autres pays de l'UE comme l'Espagne, la Bulgarie et la Hongrie. Si le rapport du SCAHAW (1998) en fait état, ces informations ne sont probablement plus actuelles.

Quelques chiffres :

- L'UE a produit environ 25.000 tonnes de foie gras en 2014 (23.000 tonnes de foie gras de canard et 2000 de foie gras d'oie).
- Le secteur génère plus de 50.000 emplois dans l'UE, et représente un chiffre d'affaires de 4 milliards d'euros.
- L'UE produit environ 90 % du foie gras mondial. Hors Union européenne, les principaux producteurs sont la Chine, les États-Unis et le Canada.
- En 2012, la Belgique comptait 13 producteurs de foie gras, produisant annuellement 25 tonnes de foie gras à partir de 50.000 canards. Cela équivaut à 0,09 % de la production mondiale (26.800 tonnes, provenant à 92 % de canards).
- Hors Union européenne, les principaux pays consommateurs de foie gras sont le Japon, la Suisse, Hong Kong et Israël.

- Le gavage des canards et des oies pour la production de foie gras est une pratique interdite dans un grand nombre de pays européens et non européens. Cependant, beaucoup de pays où la production est illégale continuent d'en importer.

Le canard mulard est un animal hybride obtenu par un croisement entre un canard de barbarie (*Cairina moschata*) et une cane domestique de type mallard (*Anas platyrhynchos*). Le mulard mâle est la variété la plus fréquemment utilisée pour le gavage en raison de son bon potentiel de production et de sa relative facilité à élever. La variété de canard domestique/mallard la plus employée est le canard de Pékin. Sauf mention du contraire, ce nom sera donc désormais utilisé ici. L'insémination artificielle a résolu en grande partie le problème de stérilité du canard mulard.

Le poids moyen d'un foie de canard mulard mâle à la fin du gavage varie entre 300g et 560g, voire plus (Babilé et al 1996, Litt et Pé 2015). Avec un foie gras de cette taille, le taux de mortalité augmente, ce qui explique la volonté des entreprises de production de réduire la durée de la période de gavage (Guémené et Guy 2004). L'utilisation de certains ingrédients, ajoutés à la bouillie de maïs pour améliorer la réponse au gavage ou la qualité du foie gras, intéresse également les producteurs. En outre, la sélection de souches parentales spécifiques entraîne une meilleure qualité des carcasses et une structure corporelle amenant un magret plus développé (la viande issue de la poitrine d'un canard mulard ou de barbarie qui a été gavé pour la production de foie gras).

Les producteurs ont développé un programme d'alimentation spécifique pour les canards, et utilisé avant la période de gavage. Il permet de réduire la durée de celle-ci par rapport à l'époque où les oies étaient utilisées et où les canards ont été pour la première fois employés (Robin et Castaing 2002, Guémené et al 2007). Ce programme se divise en trois phases :

1. Période de démarrage : Les oiseaux sont nourris *ad libitum* de l'éclosion jusqu'à un âge de 6 à 9 semaines. Ils sont d'abord confinés en bâtiment, généralement sur une litière de paille, avant de disposer d'un parcours extérieur pendant la journée.

2. Période de croissance : Les oiseaux sont rationnés sur une période de 3 à 5 semaines. Cette restriction peut être temporelle (rationnement horaire, par lequel les animaux ne peuvent se nourrir librement que pendant une courte période et une fois par jour) ou quantitative (les animaux reçoivent une portion de nourriture journalière réduite).

Généralement, les oiseaux ont accès à l'extérieur pendant la journée.

3. Période de pré-gavage : Les oiseaux sont nourris autant que possible sur une période de 3 à 10 jours (un rationnement horaire ou quantitatif peut être pratiqué, mais les volumes de nourriture sont augmentés). Le canard mulard ne possède pas de jabot défini, mais est muni d'une « bosse » à l'œsophage appelée parfois le pseudo-jabot. Cette période de pré-gavage sert à dilater l'œsophage et à stimuler les sécrétions digestives qui sont nécessaires à l'assimilation de grandes quantités de nourriture et qui entraîne le développement d'une stéatose hépatique. A la fin de cette période, le foie peut atteindre un poids de 180g, contre 80g à un état normal.

Les animaux ont normalement un accès à l'extérieur pendant la journée.

Le processus du gavage des canards est décrit dans SCAHAW (1998), Guémené et Guy (2004) et Guémené et al (2007). A un âge d'environ 12 semaines commence l'ingestion quotidienne forcée d'une quantité croissante de nourriture énergétique, riche en glucides et pauvre en protéines, et présentant un déséquilibre en acides aminés et minéraux (AVMA 2014). Pendant cette période qui dure de 12 à 15 jours, les canards sont gavés deux fois par jour. Ils reçoivent au début une ration de 180 à 200g de bouillie de maïs par repas, qui atteint ensuite 450g (et jusqu'à 1000g si l'on compte l'eau utilisée pour le mélange) par repas à la fin de la période de gavage.

Les oiseaux sont maintenus dans des cages en bâtiment, dans un environnement contrôlé.

Litt et Pé (2015) ont examiné les évolutions du marché du foie gras et dans les fermes impliquées par la production de foie gras en France, et ont pour ce faire rassemblé des données provenant d'une grande série de sources. Ces 10 dernières années, la production nationale a augmenté de 10,7 %, passant de 17.217 tonnes en 2003 à 19.067 tonnes en 2013 – dont 97,6 % à partir de canards. Les facteurs évoqués pour expliquer cette hausse sont l'amélioration du taux de conversion et la baisse de la mortalité des oiseaux. Ces changements ont eu lieu en lien avec une période de gavage plus courte, qui ne s'étendait plus que sur 12 jours en 2013 (Litt et Pé 2015). Cependant, les marges bénéficiaires ont connu une diminution tandis que les coûts ont augmenté. En France, le secteur fait actuellement face à l'obligation de recourir à des cages collectives à partir de janvier 2016, ainsi qu'à des attentes plus grandes en matière de bien-être animal de la part des consommateurs.

Le comportement, fonctionnement et hébergement normaux chez les canards sont décrits dans Rodenburg et al (2005), et chez les canards et les oies dans SCAHAW (1998). La production de foie gras d'oies est décrite en détails dans SCAHAW (1998), FAO (2002) et Arroyo et al (2012). Le bien-être des canards dans les systèmes européens d'élevages de canards est examiné dans Rodenburg et al (2005), qui se concentre sur les canards de Pékin, musqués et mulards utilisés pour la production de viande et de foie gras. Différents facteurs ayant une influence le bien-être du canard sont étudiés : la densité d'élevage et la taille du groupe, le type de sol – en caillebotis, en treillis métallique ou recouvert de paille –, l'éclairage (intensité et durée), l'accès à un parcours extérieur, ainsi que la présence d'un point d'eau pour l'abreuvement, le bain et la nage. Des problèmes de bien-être animal sont évalués, comme le picage des plumes et le cannibalisme, la peur et le stress, ou encore les maladies. Figure également une description des différents systèmes utilisés en Europe. Cette étude reconnaît que, si la présence de paille, d'un accès à l'extérieur ou d'un point d'eau offre aux canards de plus grandes possibilités comportementales (barbotage, exploration, lissage des plumes, prise de bain et nage), ces éléments doivent être correctement gérés car ils peuvent donner lieu à une mauvaise hygiène et accroître les risques pour la santé et la sécurité alimentaire. Idéalement, les installations doivent permettre l'expression des comportements naturels mais ne pas entraîner – ou du moins minimiser – des problèmes d'hygiène et de santé. Les aspects de l'élevage qui affectent le bien-être du canard mulard dans la production de foie gras sont identifiés dans cette étude comme suit :

- les réactions de peur des humains,
- la haute densité d'élevage,
- pas d'accès à un point d'eau pour le bain,
- pas d'accès à une litière,
- l'utilisation de sols en caillebotis ou en treillis métallique,
- la procédure du gavage en elle-même, et la stéatose hépatique qu'elle entraîne.

Dans leur ensemble, ces points d'attention coïncident avec les principaux aspects touchant au bien-être animal dans le cadre de la production de foie gras identifiés dans cette étude. Nous avons choisi de les diviser en cinq grandes catégories : les problèmes de santé (physique et stéatose hépatique), le gavage, l'hébergement, les problèmes comportementaux, et d'autres considérations de bien-être. Nous terminerons avec des conclusions relatives au bien-être animal et à d'autres conclusions générales. Une synthèse est également disponible ci-avant.

Conclusions

Après examen de la littérature scientifique existante, nous parvenons aux conclusions relatives au bien-être animal et aux conclusions générales suivantes :

Bien-être animal

1. En 2006, la mortalité moyenne nationale des oiseaux durant la période de gavage atteignait 2,4 % et en 2013, elle se chiffrait à 2,2 %. L'Institut Technique de l'Aviculture mentionne un taux de mortalité de 2 à 5 %. Ces chiffres sont en nette disproportion avec les taux de mortalité des canards de barbarie à l'engraissement dans les élevages anglais, qui ne s'élèvent qu'à 0,2 % durant les deux semaines précédant l'abattage.

2. Les oiseaux employés pour la production de foie gras sont les seuls animaux d'élevage qui ne peuvent utiliser leurs mécanismes biologiques fondamentaux de régulation de l'alimentation.

3. Les canards veulent par nature exprimer un comportement d'exploration : ils recherchent de la nourriture, grignotent, picorent, barbotent, mettent la tête sous l'eau et avalent. Ce besoin comportemental n'est pas respecté pendant la période de gavage.

4. Puisque le gavage empêche le canard d'exprimer son comportement – spécifique à son espèce – d'exploration et d'alimentation, son besoin de recherche et d'ingestion de nourriture n'est pas satisfait. Comme chez de nombreuses autres espèces, cet empêchement peut entraîner de la frustration.

5. Les canards reçoivent des quantités de nourriture si grandes qu'ils sont incapables de rester dans un état de satiété et d'homéostasie. Ils sont privés de leur comportement naturel d'alimentation en fonction de leur appétit.

6. Le gavage prive le canard de la maîtrise d'un aspect de sa vie qui est crucial à sa survie : l'ingestion de nourriture adaptée en quantités adaptées. La perte de cette maîtrise engendre une très forte dégradation de son bien-être.

7. Le gavage provoque chez les oiseaux un état d'obésité et des lésions aux pattes, qui réduisent sa capacité à se déplacer et engendrent vraisemblablement des douleurs.

8. Le gavage peut occasionner des blessures et des douleurs au niveau du bec, de la tête, des yeux, des narines, du cou et du canal digestif supérieur. Cependant, il n'existe pas d'études descriptives de ces conditions.

9. Les fractures osseuses et autres lésions aux ailes sont un risque qui se manifeste

surtout lors du ramassage, du transport vers l'abattoir et de l'accrochage.

10. Les canards sont forcés d'ingérer des grandes quantités d'une nourriture déséquilibrée, qui ne correspond pas à leurs besoins nutritionnels et qui entraîne d'importantes pathologies du foie, des os et d'autres organes.

11. Le gavage occasionne une pathologie du foie, plus spécifiquement une stéatose, qui répond aux attentes et aux intérêts des producteurs de foie gras, mais qui augmente fortement le risque d'une mort prématurée pour le canard.

12. L'état pathologique du foie ne fait pas de doute, preuves en sont la capacité moindre du foie à détoxifier (clairance de la BSP plus lente, demi-vie plus longue de la BSP) ainsi que les lésions aux cellules hépatiques (augmentation des enzymes du foie) à la fin de la période de gavage. Ce n'est pas parce que la stéatose est réversible que les altérations du foie ne sont pas pathologiques.

13. L'administration forcée et en grande quantité d'une nourriture carencée entraîne une hépatomégalie (élargissement du foie), ce qui peut donner lieu à de la douleur, des problèmes d'équilibre et des difficultés dans le déplacement.

14. Le foie élargi peut comprimer les sacs aériens et d'autres organes abdominaux. Par ailleurs, une encéphalopathie hépatique (les effets de toxines sur le cerveau) peut apparaître lorsque la fonction du foie est fortement compromise.

15. La grande quantité de nourriture à haute valeur énergétique que les canards doivent ingérer les place dans un état considérable de stress thermique. Ils passent une bonne partie de leur temps à haleter afin de thermoréguler et de maintenir une homéostasie physiologique.

16. Le taux de corticostérone dans le sang n'est pas un indicateur fiable de bien-être s'il est mesuré en relation avec l'alimentation du canard mulard. Le taux de corticostérone doit être examiné en lien avec d'autres indicateurs de bien-être tels que la santé, la présence de pathologie, d'autres mesures physiologiques, le comportement et d'autres indicateurs de l'état mental.

17. Les cages individuelles restreignent fortement les mouvements des oiseaux et ne leur permettent pas d'exprimer plus qu'un répertoire comportemental minimal, ce qui nuit fortement à leur bien-être.

18. Les canards sont des animaux grégaires, qui ont besoin d'un espace leur permettant d'étendre pleinement leurs ailes, de lisser leurs plumes et de faire leur toilette, de marcher, d'interagir normalement avec leurs congénères et d'exprimer d'autres comportements. Les cages collectives sont de petite taille, et offrent habituellement une surface par animal de 1200-1300 cm^2 seulement.

19. Les cages collectives sont un environnement appauvri, qui ne contiennent qu'un groupe d'animaux et des abreuvoirs. On ignore si les abreuvoirs actuellement utilisés permettent au canard l'immersion complète de la tête et la prise de bain, des comportements nécessaires au lissage des plumes.

20. Les recommandations du Conseil de l'Europe et les directives contenues dans la charte de la Fédération européenne du foie gras précisent que les canards doivent être capables d'exprimer les comportements caractéristiques de leur espèce. Pourtant, les canards élevés en groupe sont privés d'un sol leur permettant d'exprimer leur comportement d'exploration et de recherche de nourriture.

21. Contrairement aux recommandations du Conseil de l'Europe et aux directives contenues dans la charte de la Fédération européenne du foie gras, les cages collectives ne contiennent pas d'espace où les canards peuvent se reposer en groupe. L'absence de litière nuit également à leur confort et à leur propreté.

22. Le sol des cages collectives est constitué de treillis en métal ou en plastique, ce qui peut aggraver les dermatites de contact (lésions aux pattes, aux orteils, au jarret et à la poitrine).

23. Pour pallier aux difficultés de saisir et d'immobiliser les oiseaux, un système de contention a été imaginé pour les empêcher de se débattre, de résister ou de s'échapper. Ce système facilite et accélère l'acte du gavage, mais est une source de peur et a un impact négatif sur la relation entre le gaveur et l'animal.

24. Les oiseaux détenus en groupe courent un plus grand risque d'être blessés par une mauvaise technique de gavage, ou de manipulation, de se trouver coincés dans le mécanisme de contention de la cage, ou d'être confinés dans une mauvaise position sur une longue période.

25. Au fur et à mesure que les oiseaux passent par les différents stades de la production de foie gras, leur état se détériore. Des lésions cutanées douloureuses, telles que des dermatites de contact, sont fréquentes, et apparaissent assez tôt dans le processus de production. Au stade du gavage, ces lésions sont souvent graves, et peuvent s'accompagner d'autres blessures au corps.

26. Pendant les deux premières étapes de la production de foie gras, au démarrage et à la croissance, les canards n'ont parfois pas accès à un point d'eau pour la baignade, ou du moins pour l'immersion complète de la tête. Il s'agit pourtant d'un besoin pour l'entretien du plumage et du corps ainsi que pour la thermorégulation.

27. Par rapport aux groupes de contrôle, les canards gavés manifestent une série de modifications du comportement, qui indiquent une atteinte à leur bien-être : immobilité, position couchée sur de longues durées, peu de toilettage, de lissage des plumes et d'interactions, halètements prolongés.

28. L'oropharynx des oiseaux est adapté pour permettre le réflexe nauséeux, empêchant les objets – autres que la nourriture – de s'introduire dans la gorge et protégeant de l'étouffement et de l'aspiration. Au début, l'acte du gavage déclenche ce réflexe, mais celui-ci s'estompe après un certain temps. On ne connaît pas le temps d'adaptation nécessaire à la disparition du réflexe nauséeux, ni dans quelle mesure le canard en est affecté.

29. Les canards sont nourris par l'insertion d'un tube dans leur œsophage, et ce deux fois par jour sur une durée pouvant atteindre 15 jours. Ils se montrent réticents à rentrer dans l'enclos de gavage, ce qui indique une aversion pour le gavage. Il n'existe pas de preuve crédible selon laquelle les canards montrent un comportement d'évitement moindre avec le gaveur qu'avec une autre personne (inconnue).

30. D'autres problèmes de bien-être des canards se posent également, comme une peur des humains et un haut degré de nervosité et de réactivité à l'environnement. Les canards réactifs, nerveux et craintifs supportent moins leur environnement, ce qui représente une atteinte à leur bien-être.

31. Les conditions actuelles de la production de foie gras, ne respectent que trois des douze critères et pas un seul principe de bien-être que prévoient le projet Welfare Quality®.

Général

1. Ces 10 dernières années en France, la production de foie gras a augmenté de 11 %, passant de 17 217 tonnes en 2003 à 19 067 tonnes en 2013, dont 98% à partir de canards. Les marges bénéficiaires ont diminué tandis que les coûts ont augmenté.

2. Les oiseaux migratoires possèdent des mécanismes de stockage de nourriture avant la migration. L'oie cendrée *Anser anser*, la principale espèce qui était traditionnellement utilisée pour la production de foie gras, est migratoire. Ce n'est en revanche pas le cas du canard musqué ni du canard mulard, et la plupart des espèces de mallards sauvages migrent assez peu. Le stockage de nourriture avant la migration peut amener une augmentation du foie, mais probablement pas plus qu'un doublement de sa taille.

3. A la fin de la période de gavage, le foie du canard atteint un volume de 7 à 10 fois supérieur à sa taille normale. Son poids est de 550g à 700g et contient une concentration de lipides de l'ordre de 56 %. Cette augmentation du poids du foie entraîne une augmentation du poids corporel de 50 à 85 %.

4. Un foie gras est le résultat d'une augmentation de la lipogenèse hépatique, d'une capacité insuffisante du foie à exporter les triglycérides néo-synthétisés, et d'une capacité limitée des tissus périphériques à stocker les lipides circulants, ce qui favorise le retour de ces lipides vers le foie.

5. La suralimentation spontanée peut être stimulée en manipulant la durée de la luminosité et le nourrissage, généralement par une restriction suivie par une alimentation ad-libitum. Cette méthode pourrait donc permettre une production de foie gras sans gavage.

6. Pour pallier aux difficultés de saisir et d'immobiliser les oiseaux élevés en groupe pour l'acte du gavage, un système de contention a été imaginé pour les empêcher de se débattre, de résister ou de s'échapper. Ce système consiste en une paroi mobile qui pousse les oiseaux vers l'avant de la cage, et en une paroi verticale frontale qui s'abaisse sur eux pour les empêcher de s'échapper ou de bouger (« peigne de contention »).

7. Par rapport aux cages individuelles, l'hébergement collectif entraîne une baisse du poids du foie, une augmentation du poids du magret, une augmentation de la durée nécessaire pour l'acte du gavage, et une augmentation du volume d'eau utilisée pour le nettoyage. A l'abattage apparaissent une hausse des troubles hépatiques, moins d'hématomes mais plus d'écorchures sur la carcasse.

8. La consommation de foie gras peut être nocive pour la santé humaine. La protéine amyloïde contenue dans le foie gras de canard ou d'oie pourrait accélérer le développement de l'amylose dans une partie de la population humaine.

VERSION ORIGINALE

The Welfare of Ducks during Foie Gras Production

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The Welfare of Ducks during Foie Gras Production

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14 September 2015

This review of the scientific literature on foie gras production in waterfowl focusses on how the welfare of the birds may be affected by this farming practice. We concentrate on the research on ducks rather than geese, because ducks are used in over 97 % of foie gras production in France (18,600 tons in 2013) (Litt and Pé 2015). In 2012 Belgium produced approximately 25 tons of foie gras, 92% from ducks (Federale overheidsdienst 2014).

The large majority of publications in scientific journals on foie gras production come from researchers from INRA (Institut National de Recherches Agricoles) and from ITAVI (Institut Technique de l'Aviculture) in France, where there are centres dedicated to this type of research. We are very grateful to Dr D. Guémené of INRA and to Dr J. Litt of ITAVI, who provided us with references and were very helpful in answering our questions.

Because of the limited amount of published peer-reviewed scientific literature on the welfare of ducks during foie gras production, we have also consulted conference proceedings, in particular proceedings from the biennial 'Journées de la Recherche sur les Palmipèdes à Foie Gras', as well as technical brochures and stand-alone texts from known sources available on the internet. Wherever possible, we have tried to avoid using material from groups advocating for or against the production of foie gras, and we have avoided using unsubstantiated material from dubious sources or personal opinion.

Campaigns against foie gras production have been led by a large number of animal charities and organizations, some of which have prepared reports, documentaries and similar presentations on the subject which are available online. The charities include the British Columbia SPCA, Compassion in World Farming, GAIA (Global Action in the Interest of Animals), the Global Action Network, the Humane Society of the United States, L-214 Ethics and Animals, OneKind (formerly Advocates for Animals), Viva!, World Animal Protection (formerly World Society for the Protection of Animals), and others. There are concise reviews from the American Veterinary Medical Association (JAVMA 2014) and the Canadian Veterinary Medical Association (Skippon 2013). There are also many organizations that promote the production and consumption of foie gras.

The terms force-feeding or gavage are used interchangeably in this review. The main food used, maize, is usually called corn in North America. Other terms, such as assisted feeding, cramming, and over-feeding, are sometimes used in the literature but mean the same as force-feeding or gavage. Much of the literature on foie gras production is in French. In some instances, approximate translations have been used because the equivalent word does not seem to exist in English (e.g. nervosisme, peigne de contention).

We should like to thank the Belgian charity GAIA for supporting the preparation and writing of this report at the University of Cambridge. The report focuses on the available scientific and other factual information and its content is independent of funding.

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Executive Summary

This review of the scientific literature on foie gras production focuses on ducks and how their welfare may be affected by this farming practice, in particular by force-feeding. While the production of foie gras is recognised as being part of France's long gastronomic tradition it is worth noting that, historically, geese were used rather than ducks. In the past 10 years (2003 to 2013), national production has increased by 10.7%, with 97.6% coming from ducks. Current challenges to the sector in France include the compulsory switch to group housing by January 2016, together with an expectation of greater consideration of animal welfare by some consumers. The switch to group housing has already occurred in Belgium.
With force-feeding the duck lacks control over an aspect of its life that is crucial to its survival, the ingestion of appropriate quantities of an appropriate diet. This loss of control leads to very poor welfare.

Effects on health

Limited mortality figures are available for ducks used to produce foie gras. In 2013 the national average mortality was 2.2% (Litt and Pé 2015). SCAHAW (1998) identified abnormalities in standing posture and gait, due to the enlarged fatty liver and other pathology such as bone fragility and foot lesions. More recently, Litt et al described the development (2015a) and application (2015c) of an evaluation grid to assess the physical condition of mulard ducks. The condition of the birds deteriorated as they passed through the successive stages of production. Wing damage, including humeral fractures, was frequent and most likely to occur at the stages of collection, transport to the abattoir and shackling. Pododermatitis, hock burn, breast lesions, back injury (most commonly scratches) and oesophagus (pseudo-crop) injuries were identified as useful measures to assess duck welfare.

There are studies comparing the extent of extravasation after nociceptive stimulation with the force-feeding procedure, with evidence of oesophagitis in force-fed birds (Servière et al 2002, 2011). However, there are few data on post-mortem findings, at a gross and microscopic level, of the upper digestive tract before, during and at the end of force-feeding. It seems that the likelihood of injury may be greater with group housing because of the need to catch, position and restrain the birds.

The mulard duck is not migratory and never develops a greatly expanded liver when reared normally. Yet by the end of the force-feeding period, its liver is 7 to 10 times the size of a normal one with an average weight of 550 to 700 g and a fat content of 55.8%. Steatosis and other changes in the liver, as a result of feeding management for foie gras production and force-feeding in particular, are pathological and can limit duck survival. The reduction in the liver's ability to detoxify, as indicated by a slower BSP clearance, longer BSP half-life and raised liver enzymes at the end of the force-feeding period, are all clear evidence of clinical pathology.

Direct effects of force-feeding

Ducks show a range of behavioural responses to force-feeding, such as increased agitation for the first 3 days, followed by increased periods of rest, wing flapping and head-shaking, less time with their head at rest, less grooming and preening behaviour and reduced mobility. Due to the large amount of food that is force-fed, much of the ducks' time is spent panting in order to disperse the extra heat generated from digestion. This thermal stress makes them very prone to environmental heat stress, which adds further to their discomfort. The description and interpretation of behavioural changes around force-feeding from an animal welfare perspective is lacking in many studies.

Faure et al (2001) compared the responses of force-fed ducks to the force-feeder with their response to an unfamiliar person. The choice of response measure (flight distance for a bird that is in a very small cage) and a confounding effect of the familiarity of the force-feeder make the conclusion that force-feeding is not aversive to ducks scientifically invalid. Repeating this experiment using a better measure and two persons of equal familiarity, with one doing the force-feeding and the other not, could provide valid results.

There are studies of corticosterone and the HPA axis as indicators of stress in ducks during force-feeding, but they vary greatly in experimental design. A complicating factor is that food can suppress any increase in glucocorticoids and activity can increase it. The results of Guémené et al (2001, 2006a) and Flament et al (2012) on corticosterone levels before and after force-feeding are not in agreement with those of Mirabito et al (2002c) and Mohammed et al (2014). We conclude that levels of blood corticosterone are a poor indicator of welfare in the studies reported on mulard ducks.

Attempts have been made to stimulate spontaneous over-eating in geese by manipulating day length and feeding regimes, usually restriction followed by *ad-libitum* feeding (Guy et al 2013). It seems that, under specific conditions of feeding and photoperiod, geese are able to initiate spontaneous liver steatosis, offering the possibility of foie gras production without the need to force-feed. However, this alternative method currently has great negative impacts on the environment and some consumers do not like the liver produced.

There may be a public health risk associated with foie gras consumption. Duck or goose-derived foie gras contains amyloid protein, which could hasten the development of amyloidosis in a susceptible human population.

Housing

The keeping of ducks in cages scarcely larger than their bodies, and with the head and neck protruding so that force-feeding can occur, causes very poor welfare. After January 2016 individual caging of ducks for foie gras production will be illegal in France, and should be replaced by group housing. Group housing has already been implemented in Belgium. Group housing allows social interactions between birds and gives them more space as a group. Compared with individual cages, group housing leads to a decrease in liver weight, an increase in the time taken to perform the force-feeding, and an increase in the amount of water used in cleaning. There is a slight increase in the weight of the 'magret' (Litt 2010, Mirabito et al 2002a), an increase in liver defects at slaughter and fewer haematomas but more scratch lesions on the carcasses.

Guémené et al (2002, 2006b) found that the capture and immobilisation of group-housed birds for force-feeding can be a cause of repeated stress. A containment (restraint) method has been developed to overcome the problem of birds trying to escape, struggling or retreating to the back of the group cage and hence being difficult to force-feed. Group-housed birds may be more susceptible to injury from handling, getting caught in the cage's containment mechanism, or restrained for a long time. Most cages are rather small, with a surface area per bird of 1200 cm^2 to 1300 cm^2 and a mesh floor made of steel or plastic. Despite Council of Europe (1999) recommendations, neither litter, a resting place nor bedding material is provided. This is likely to lead to a worsening of contact dermatitis, which is already present at the starter and grower stages of foie gras production (Litt et al 2015c), and also affect duck comfort, foraging and exploratory behaviours, and social interactions.

Ducks have a need for open water, for example in a trough or bath, to maintain plumage and body condition and to thermoregulate. It is legally required in many countries that ducks should be able to fully immerse their head, to allow water to cover the head and be taken up by the beak so that they can shake water over their body without difficulty. Water troughs attached to the cages are provided for force-fed ducks. However, the minimum width and depth dimensions of troughs for this have not been established, and to our knowledge there are no studies so far on trough use or on water cleanliness and behaviours of force-fed ducks at the troughs. It also seems that this facility is not always provided for ducks in the first two stages of foie gras production.

Behaviour

Mulard ducks are most often used for foie gras production, and some are recognised as being particularly fearful, nervous and hyper-reactive – the term 'nervosisme' is used in French. They show panic and flight responses to the approach of humans and are generally described as being 'sensitive to the environment' (Guémené et al 2002, Guémené et al 2006b, Laborde and Voisin 2013). In small individual cages, there must be fear of humans in the ducks but, as they cannot move, it is not a problem for the force-feeders. The move from individual to group housing seems to have brought the problem of "nervosisme" in ducks to the fore. Mulards show obvious panic responses and fear of humans, and appear to be more sensitive to social stress (isolation from other ducks) than the two parent types (Arnaud et al 2008). They also have higher basal levels of corticosterone than parental lines.

Aspects of husbandry and management prior to force-feeding that may affect the birds' behaviours during force-feeding have been investigated by extensive questionnaire and telephone surveys of force-feeders and duck farmers (Laborde and Voisin 2013). Reactive, nervous and fearful ducks clearly have poorer welfare than calm ones, because they are less well able to cope with environmental changes and with the presence of humans.

Other welfare considerations

There is substantial evidence that negative interactions between humans and animals increase the animals' fear and stress (Hemsworth 2007). In the case of foie gras production, the relationship between the force-feeder and the force-fed ducks has received little attention but the responses seen, such as struggling and escape behaviours, are typical of farm animals subjected to routine procedures that they find painful, frightening and unpleasant (Vinuela-Fernandez et al 2011).

The four welfare principles and 12 criteria proposed by the Welfare Quality® project (Blokhuis et al 2010) present general guidelines on the needs of animals and how they may be met. Based on the information available to us, and contrary to the aspirations of the European Federation of Foie Gras Charter, only three of the 12 criteria and none of the welfare principles are met in current systems of foie gras production. Ducks and geese in foie gras production are the only farmed animals that are not allowed to use their basic biological mechanisms to regulate their own food intake.

While the primary aim of this review has been to highlight the welfare problems in the last stage of foie gras production, when ducks are force-fed, welfare problems have also been identified in the first two stages, starter and growth. These include the early, frequent and rapid development of footpad dermatitis, hock burns and breast blisters, fear of humans and high sensitivity to the environment, and lack of access to open water for bathing or at least full immersion of the head.

Introduction

In 1998, the Scientific Committee on Animal Health and Animal Welfare (SCAHAW) produced a report on the welfare aspects of foie gras production in ducks and geese for the European Commission (SCAHAW 1998), and concluded that “force-feeding is detrimental to the welfare of the birds.” French researchers, who studied several parameters during force-feeding and did not find scientific evidence to support the conclusion of SCAHAW, have objected to this conclusion (Guémené and Guy 2004).

The foie gras producing countries in the European Union are France, Belgium, Bulgaria, Hungary and Spain (Litt and Pé 2015). A description of the background to foie gras production in France can be found in Guémené and Guy (2004) and in SCAHAW (1998). French law (French rural code L654-27-1) states that "Foie gras belongs to the protected cultural and gastronomical heritage of France". However, the long tradition in France was to use geese rather than ducks so the practice has changed in a substantial way.

The European Federation of Foie Gras Producers was established in 2008 and has members from the five European countries that produce foie gras. Their website provides production data and seeks to uphold and defend the production of foie gras (see http://www.eurofoiegras.com/en/). Additional information on foie gras in Belgium and Europe in general can be obtained from a recent Belgian scientific report commissioned by the Belgian Council on Animal Welfare (Federale overheidsdienst 2014). The two main areas of concern identified by the Belgian report are 1) whether force-feeding is an ethical practice with regard to society’s obligations towards animals and 2) the welfare of the force-fed ducks, especially when they become obese towards the end of force-feeding.
We were unable to find reliable information for production methods in other EU countries such as Spain, Bulgaria and Hungary; some is presented in SCAHAW (1998) but is likely to be out-of-date.

Some general data are presented below:

- Approximately 25,000 tonnes of foie gras were produced in the EU in 2014 (23,000 tonnes of duck foie gras and 2,000 tonnes of goose foie gras).
- The sector generates more than 50,000 jobs in the EU, with a turnover of **4** billion euros**.**
- The EU produces approximately 90% of the world’s foie gras. The other main producing countries are China, the United States and Canada.
- There were 13 producers of foie gras in Belgium in 2012, producing about 25 tons of foie gras every year from 50,000 ducks, which is approximately 0.09% of global production (26,800 tons with 92% from ducks).
- Japan, Switzerland, Hong Kong and Israel are the main non-EU countries that consume foie gras.
- The force-feeding of ducks and geese for the production of foie gras is banned in a large number of European and other countries, but many countries where production is banned continue to import it.

The male mulard duck, the mulard duck being a hybrid between a muscovy drake (*Cairina moschata*) and a female domestic duck (*Anas platyrhynchos*), which is a mallard, is used most frequently for force-feeding purposes because it has a good potential for production and is relatively easy to manage. The breed of domestic duck/mallard most often used is the Pekin, so this name will be used here unless specified otherwise in a publication. Infertility problems in the production of this mulard hybrid have been mostly solved using artificial insemination.

The average weight of a foie gras liver produced in the male mulard duck is from 300 g to 560 g or more (Babilé et al 1996, Litt and Pé 2015). With such a large fatty liver, mortality rates increase so a focus of production companies is to reduce the duration of the force-feeding period (Guémené and Guy 2004). Producers have also investigated the use of certain ingredients, added to the maize mash, which enhance the response to force-feeding or improve the quality of the foie gras. In addition, there is selection of parental strains for better carcass quality and for a body conformation to produce larger breast muscle known as 'magret' (the breast meat of a mulard or muscovy duck that has been force-fed to produce foie gras).

Producers have developed a specific feeding programme adapted to ducks, which is used prior to the force-feeding period and leads to a reduction in the duration of force-feeding as compared with the duration when geese were used and when ducks were first used (Robin and Castaing 2002, Guémené et al 2007). It can be divided into three phases:

1. Starting period: Birds are fed *ad libitum* from the time of hatching until 6 to 9 weeks. They are initially kept indoors, usually on straw as litter, and eventually allowed outdoors during the day.

2. Growing period: Birds are feed-restricted for a period of 3 to 5 weeks. This restriction may be in time (hourly feed restriction, when birds are fed *ad-libitum* but for only a short period, once daily) or amount (quantitative feed restriction, when birds are fed a reduced amount of food daily).
Birds normally have outdoor access during the day.

3. Pre-force-feeding period: Birds are fed as much as possible for 3 to 10 days (hourly or quantitative feed restriction may be used, but feeding increasing amounts). There is no defined crop in the mulard duck; an oesophageal 'out-pouching' is sometimes called the pseudo-crop. This procedure before force-feeding has the aim of dilating the oesophagus and stimulating the digestive secretions necessary for the assimilation of a large amount of food, and starting the process of liver steatosis. The liver can weigh up to 180 g by the end of this period, compared with 80 g normally.
Birds normally have outdoor access during the day.

The force-feeding procedure in ducks is described in SCAHAW (1998), Guémené and Guy (2004) and Guémené et al (2007). After about 12 weeks of age there is forced daily ingestion, usually lasting 12 to 15 days, of increasing amounts of energy-rich food with a high carbohydrate, low protein content and an uneven amino acid and mineral balance (AVMA 2014). Ducks are force-fed twice daily; at the beginning each receives 180 to 200 g of maize per meal, increasing to 450 g (and to 1000 g when water is added to make mash) per meal towards the end of the force-feeding period.

They are kept indoors in cages and in a controlled environment.

Litt and Pé (2015) reviewed developments in the foie gras market and in farms involved in the production of foie gras in France, collecting data from a range of sources. In the past 10 years, national production has increased by 10.7%, from 17,217 tonnes in 2003 to 19,067 tonnes in 2013 with 97.6% coming from ducks. Factors responsible for this production increase are said to be improved feed conversion efficiency and a reduction in bird losses. This has occurred with a shortening of the force-feeding period to just over 12 days by 2013 (Litt and Pé 2015). Nevertheless, profit margins have decreased as costs have increased. Current challenges to the sector in France include the compulsory switch to group housing by January 2016, together with an expectation of greater consideration of animal welfare by consumers.

The normal behaviour, functioning and husbandry of ducks is described in Rodenburg et al (2005), and of ducks and geese in SCAHAW (1998). Foie gras production in geese is described in detail in SCAHAW (1998), FAO (2002) and Arroyo et al (2012). The welfare of ducks in European duck husbandry systems is reviewed in Rodenburg et al (2005), focusing on Pekin, muscovy and mulard duck genotypes used for meat and foie gras production. Factors that can affect duck welfare, such as stocking density and group size, slatted, wire-mesh or straw-based flooring, lighting (intensity and duration), access to an outdoor run, and the provision of open water for drinking, bathing and swimming, are discussed. Welfare problems such as feather pecking and cannibalism, fear and stress, and diseases are assessed, and the various systems in use in Europe are described. The review acknowledges that while giving ducks access to straw, an outdoor run, or open water increases their behavioural opportunities (dabbling, foraging, preening, bathing, and swimming), this must be done in an optimal way because it can lead to poor hygiene and increased risks to health and food safety. Good practical solutions have to allow the expression of natural behaviours but not lead to, or at least minimize, hygiene or health problems. Specific husbandry features that affect the welfare of the mulard duck in foie gras production are identified in the review as:

- fear reactions to humans
- high stocking density
- no access to water for bathing
- no access to bedding
- use of slatted or wire mesh floors
- the force-feeding procedure itself and the consequent liver steatosis.

These concerns are broadly in agreement with the main aspects of welfare associated with foie gras production that we have identified in this review. We have chosen to address these in five broad categories: health problems (physical and liver steatosis), force-feeding, housing, behaviour problems, and other welfare considerations. We finish with a list of animal welfare-related and general conclusions. An executive summary is presented on page 5.

Health

Mortality

Published data on the effects of force-feeding on duck health, and hence on a key aspect of duck welfare, are lacking (Servière et al 2011). Limited mortality figures are available for ducks used to produce foie gras and it is difficult to find a reasonable baseline for comparison, such as the mortality rate of non force-fed mulard ducks. SCAHAW (1998) concluded that mortality during the force-feeding period was typically 2 to 4%. The Institut Technique de l'Aviculture (ITAVI, Technical Institute of Poultry Farming) reports a figure of 2 to 5%, in 2006 the national average mortality of force-fed birds was 2.4% (Laborde et al 2010) and in 2013 it was 2.2% (Litt and Pé 2015).
In an experimental study which explored the effects of group size and stocking density on a number of production measures, the mortality of ducks kept in groups of 3, 6 or 9 and at stocking densities of 1000, 1500 and 2000 cm^2 per bird ranged from 1.4% to 13.9%, with the highest mortality seen in the largest group with the highest stocking density (9 ducks with 1000 cm^2 floor space each). The average mortality was 5.6% (Mirabito et al 2002a). These data compare unfavourably with mortality rates of muscovy ducks in fattening units for meat production, where in the two weeks before slaughter the mortality rate was 0.2% (SCAHAW 1998). On farms in the UK, mortality rates were 5.2% for Pekin ducks reared to an average 3.35 kg at 48 days (Jones and Dawkins 2010a) and less than 5% in a commercial trial evaluating open water sources for farmed ducks over 43 days (Liste et al 2012). Most mortality in ducks reared for meat would occur in the youngest birds but even if mortality rate varied in a linear way with age, the expected rate for 12 days of 5.2% over 48 days would be 1.3%.
Anecdotal observations by members of the European Scientific Committee on Animal Health and Welfare (SCAHAW 1998) suggest that fattened ducks demonstrate abnormalities in standing posture and gait. This has occurred to the extent that mortalities have been attributed to some ducks becoming immobile and therefore unable to access water.

Physical health

The health of birds can be measured using a wide range of variables including body anatomy, posture, walking ability and gait, face, body and plumage condition, presence and severity of visible skin lesions (footpad, toe and hock dermatitis, breast lesions) as well as mortality (Jones and Dawkins 2010a, Liste et al 2012). These variables inform us of the animals' welfare and also of management procedures. For example, the condition of the face, i.e. cleanliness of the nostrils, eyes and feathers, informs about whether or not the duck is able to immerse its head fully under water and keep its face clean. The presence of facial injuries provides information about the physical damage done during the force-feeding procedure.

Ducks that are being force-fed large quantities of food demonstrate abnormalities in standing posture and gait, due to the enlarged liver and other pathology such as bone fragility and foot lesions. The abnormal mineral balance in the diet that force-fed birds receive is thought to lead to bone pathology which is compounded by the bird's weight and limited opportunities to build bone and muscle strength. Typically, bone fractures occur on wing bones, mainly the humerus, and the prevalence of bone fractures due to handling at slaughter is between 30 and 70% (SCAHAW 1998). Other factors will also increase susceptibility to injury and distress during transport, such as fear of humans, obesity and substantially higher thermoregulatory demands than those for normal ducks.

There are few studies of the effects of force-feeding on gross body anatomy. SCAHAW (1998) observed, on visits to fattening units, that the legs of the force-fed animals were pushed outwards, away from the midline of the body so that they met the ground considerably further apart than is normal. The leg could not be held vertically when the bird was standing or walking, and they concluded that this was caused by the great expansion of the liver. They observed that the consequence was that birds with expanded livers had difficulty in standing and their natural gait and ability to walk were severely impaired. They assumed that there must be increased lateral force on the leg joints when birds with hypertrophied livers are standing or walking but this has not been studied.
The use of individual cages, in which the birds cannot stand in a normal standing position or walk, occurs in some countries but is expected to decline in France following a change in the law. Individual caging has already been banned in Belgium. These cages make it difficult to recognise leg problems and leg pain. In the study by Carrière et al (2006b) on the behaviour of force-fed ducks kept in groups, the ducks spent more time lying down and walked less frequently and for a shorter time than control ducks (non force-fed but kept in the same conditions). The reasons for this were ascribed to the birds' increased weight, but the mechanisms by which increased weight led to reduced activity were not explored. It is possible that the excessive force on leg joints caused pain, which led to a reduced inclination to walk. In addition, hypertrophied livers can cause discomfort in a number of other species so some discomfort may have resulted directly from the enlarged liver in force-fed birds (SCAHAW 1998). Measures such as posture and walking ability (gait) are commonly used in the assessment of welfare of ducks (Jones and Dawkins 2010a, Liste et al 2012).

Recently, Litt et al described the development (2015a) and application (2015c) of an evaluation grid ('grille d'évaluation') to assess the physical condition of mulard ducks. The grid was applied to 63 groups of ducks on 44 different commercial farms at the end of the three main stages of production: starter, grower and gavage ('fattening'). Birds in the gavage group were evaluated after slaughter in an abattoir. Different indicators were used for the different stages; for example, cleanliness at the end of the starter phase, feathering at the end of growth and pseudo-crop lesions at the end of gavage.
The average condition of the birds deteriorated as they passed through the successive stages of production. Four physical abnormalities were noted at all three stages: dermatitis of the footpad, toe (digit) and hock (hock burn), and damage (degree of feathering or lesions) to the breast area (anterior sternum). Some lesions, such as those caused by dermatitis of the footpad and toe, appeared very early on in the production process and were present very frequently. However, they did not seem to worsen during gavage.
Lesions on the breastbone could be extensive and frequent by the end of gavage, especially in winter. Ventral loss of feathering was also commonly noted, especially

during the growth stage. Wing damage was observed at slaughter. It was judged that 88% of wing lesions were recent and probably occurred at the stages of collection, transport to the abattoir and shackling. Other body injuries, such as scratches to the dorsal part of the body, pseudo-crop injury and joint abnormalities, were noted after slaughter. Overall, the prevalence of lesions varied greatly between farms and groups of birds, and associations with fixed factors such as starter density and season were not sufficient to explain this variability.
The study did not provide figures on the prevalence of lesions at each stage. What is clear, however, is that the welfare of the birds, as assessed by general condition, deteriorated significantly as they progressed through the production stages. The authors recommend that pododermatitis, hock burn, breast lesions, back injury (most commonly scratches) and pseudo-crop injuries are useful measures that should form part of an evaluation grid to assess the welfare of the mulard duck during the three stages of production.

Contact dermatitis is an umbrella term that includes footpad and toe dermatitis (also known as pododermatitis or foot burn), hock burns and breast blisters in poultry (Shepherd and Fairchild 2010, Hepworth et al 2011). Hock burns and breast blisters are thought to be manifestations of the same condition that results in pododermatitis (Shepherd and Fairchild 2010). Lesions can vary in size and depth (Bassett 2009, Litt et al 2015b) and scales for the grading of their severity have been developed (Haslam et al 2007, Bassett 2009, Litt et al 2015b). Pododermatitis lesions are characterised by inflammation and necrosis, ranging from superficial to deep, on the plantar surface of the footpads and toes (Shepherd and Fairchild 2010). Deep ulcers may lead to abscesses and thickening of underlying tissues and structures (Greene et al 1985). Hock burns and breast blisters are not usually associated with bacterial infections.
Sudden changes in intestinal flora when ducks are force-fed can lead to gastro-intestinal upset and diarrhoea. An increase in total flora load and in faecal streptococci has been noted in the first stages of force-feeding. Enteric flora overgrowth and infections may exacerbate any existing footpad and breast dermatitis and blisters, and be a cause of mortality in force-fed birds (Laborde et al 2010).
Contact dermatitis causes significant economic loss and is also a cause of pain, disability and poor welfare. The condition is painful because of the associated tissue trauma (Haslam et al 2007). Animal welfare audits often use pododermatitis, hock burn and breast lesions as indicators of housing conditions and bird welfare (Haslam et al 2007, Hepworth et al 2011).

In a survey of Pekin ducks commercially reared for meat in the UK, the physical and plumage condition of the ducks was recorded at two ages, 23 and 41 days (Jones and Dawkins 2010a). This included eye, nostril and feather state, posture, walking ability, feather cleanliness, footpad dermatitis, callous toe and stubbly quill (short broken feathers on the breast). At 23 days, more than 98% of inspected ducks were scored as having clean eyes, nostrils and feathers and almost 98% walked upright, although walking ability was variable. At 41 days approximately 84% and 67% of ducks had clean eyes and feathers and 98% clean nostrils with over 94% having an upright posture. The birds' condition deteriorated between 23 and 41 days, but this was not marked. At slaughter, the incidence of moderate and severe footpad dermatitis lesions was 10% and 3%, 32% of ducks had calloused toes and 11% had pink hocks. Contact dermatitis lesions were mild and general condition good in other commercial trials evaluating open water sources for farmed ducks over 43 days (O'Driscoll and Broom 2011, Liste et al 2012).

The frequency of poor welfare associated with such health problems in ducks reared for foie gras production is much higher than that described above for ducks reared for meat production. Litt et al (2015b) found that by 14 weeks of age, the end of gavage, all duck foot samples had moderate to marked signs of epidermal ulceration, visible to the naked eye. Very severe ulcerative lesions, sometimes with secondary pustular infections, were noted in some birds. From the recent published data on force-fed ducks, it seems that pododermatitis is common, develops early in their lifetime and worsens with age. Biija et al (2013) studied ducks during the period prior to gavage, when they were allowed outdoor access either onto a meadow with scattered trees or onto woodland. At 9 and 11 weeks of age, both groups had developed moderate to severe pododermatitis, especially the group with woodland access.

There are some limitations in comparing birds kept in different systems. While force-fed ducks are similar to ducks kept for normal meat production in that they are fast-growing, reach heavy bodyweights and often have reduced mobility at the end stages of production, force-fed ducks are kept for longer, gain proportionally much more weight, and are housed, managed and fed differently. Ducks confined in small individual cages are not able to walk so walking difficulties might not be noticed. The recent studies, and the creation of an evaluation grid, are the first steps towards the development of an evidence-based welfare assessment protocol for force-fed ducks.

The assessment of animal welfare is performed, wherever possible, using a wide range of indicators such as the animal's health, physiological state, behaviour and mental state (Broom and Fraser 2015). The study by Litt et al (2015c) gives us an insight into what the animal is feeling, as contact dermatitis lesions are painful (Haslam et al 2007). Further studies are needed, in particular those that focus on the animals' physical condition and behaviour during gavage. However, in view of the early appearance of contact dermatitis lesions and the general deterioration of the animals' body condition, the earlier production stages (starter and grower) should also be examined. Finally, the high proportion (88%) of recent wing lesions that probably occurred at the stages of collection, transport to the abattoir and shackling also cause very poor welfare and should be studied and prevented.

Reports of post-mortem examinations of ducks that die during or at the end of the force-feeding period are sparse in the scientific literature. In general, there is insufficient information on injuries and death due to force-feeding, on the incidence of secondary infections of the oesophagus (such as Candidiasis, a yeast infection due to *Candida albicans*) and on other complications that may arise. SCAHAW (1998) report that, in one study, secondary infections with *C.albicans* were present in up to 6% of birds. In an internet presentation on the mulard duck used for foie gras production Guérin (2015), a French veterinary surgeon from the École Nationale Vétérinaire, Toulouse, lists the main causes of illness and death during the force-feeding period. The main illnesses are respiratory and ocular disease, locomotor disorders (loss of balance, myositis), digestive disorders (oesophagitis, candidiasis, enteritis) and focal necrosis of the liver. Causes of death at the beginning of gavage include cholera (*Vibrio cholerae*) and at the end include respiratory insufficiency and disease, enteric disorders, cardiac myopathy and other causes such as cloacitis, ascites and liver haemorrhages.

The act of gavage, where a rigid tube is inserted into the upper digestive tract, clearly has the potential to be painful if performed rapidly or without due care. Therefore, the condition of the oesophagus and pseudo-crop before, during and at the end of force-feeding is of particular interest. A number of studies have looked for histological evidence of pain in ducks at different stages of the force-feeding period. Servière et al (2002) describes signs of sub-acute moderate and multifocal oesophagitis in force-fed birds. Inflammatory foci may develop as a result of effects of abrasion and distension caused by the boluses of food on tissues of the upper digestive tract. In another experiment, ducks that were force-fed were compared with pharmacologically treated control ducks, in which necrosis of the oesophagus was provoked under anaesthesia by an irritating substance containing mustard oil. Local inflammatory processes resulting in focal extravasation responses, revealed by a specific marker, were very severe in control ducks, but were not observed in force-fed ducks at the beginning or the middle of the force-feeding period. However, areas of extravasation were observed in a few ducks by the end of force-feeding and were probably due to moderate inflammation. Observations of peripheral and central neuronal activation showed indications of pain signaling in the brain and spinal cord of chemically treated birds, and low level signaling in force-fed ducks (Servière et al 2002).

More recently, further experiments similar to the one described above were carried out, but hydrochloric acid (HCl) was used instead of mustard oil as an irritating chemical substance to induce neurogenic inflammation of the upper digestive tract (Servière et al 2011). Four regions of the upper digestive tract were examined, and in the case of force-fed ducks, four different feeding periods as well. The authors conclude that compared with extravasation after chemical nociceptive stimulation, the mechanical insult to the oesophageal walls, potentially associated with the 'preparation for force-feeding' phase and with the force-feeding procedure, is moderate. The question remains whether mechanical stimulation, such as excessive distension, induces visceral nociception.

While there are studies comparing the extent of extravasation after nociceptive stimulation with the force-feeding procedure, there is a lack of data on post-mortem findings, at a gross and microscopic level, of the upper digestive tract before, during and at the end of force-feeding. Descriptive studies of the injuries, the incidence of secondary infections of the upper digestive tract, and information on other complications that may occur as a result of force-feeding, such as injuries and lesions on the face and eyes, are needed. This is particularly urgent as it seems that the likelihood of injury may be greater with group housing because of the need to catch, position and restrain the birds.

Liver steatosis

Some migratory waterfowl, such as greylag geese *Anser anser,* the same species as the domestic goose, eat more than the normal amount of food in the days before migration. The muscovy and the mulard duck are non-migratory and most populations of wild mallard migrate little. Unlike the greylag goose, traditionally the main species used for foie gras production, the mulard duck and its two parental species never have a greatly expanded liver when reared normally. Force-feeding results in an increase in liver size and fat content. By the end of the force-feeding period, the duck's liver is 7 to 10 times the size of a normal liver with an average weight of 550 to 700 g and a fat content of 55.8%. This increase in liver weight is accompanied by a substantial overall live-weight gain in the range of 50 to 85%. In comparison, the average weight of a liver of a non force-fed drake is 76 g with a fat content of 6.6% (Babilé et al 1996).

Steatosis and other changes that are caused in the liver, as a result of general management for foie gras production and force-feeding in particular, are pathological and can limit the survival potential of the ducks. The enlarged liver may compress airsacs, reducing respiratory capacity, and other abdominal organs and where liver function is severely compromised hepatic encephalopathy (central nervous dysfunction due to effects of toxins such as ammonia on the brain) may develop (SCAHAW 1998, Broom and Fraser 2015).

Steatosis develops because of the accumulation of triglycerides in hepatocytes (liver cells); a detailed illustration of the process is presented in Baéza et al (2013). Maize, consisting mainly of starch and low in fat and protein, is fed in large amounts. This stimulates two transcription factors regulated by insulin, SREBP-1c, and by glucose, ChREBP, which promote glycolysis and lipogenesis. Fatty liver results essentially from an increased capacity of hepatic lipogenesis, an insufficient hepatic capacity to export newly synthesised triglycerides, and a limited capacity of peripheral tissues to take up circulating lipids, thus favouring their return towards the liver. There is failure of the liver to release fat into the blood, hypertrophy of hepatocytes which accumulate fat together with other components (water, minerals, proteins, phospholipids), and decreased retention of essential fatty acids.

The synthesis of lipids in the liver is maximised when the food fed during gavage is high in starch and low in protein. To reduce the ducks' capacity to make Very Low Density Lipoprotein (VLDL), which carries lipids away from the hepatocytes to peripheral tissue, the diet is restricted in levels of certain nutrients necessary for their synthesis such as the amino acids methionine and choline (Gabarrou et al 1996). Maize has high levels of thiamine and biotin, which are necessary for the conversion of sugars to lipids. Force-feeding a high-energy, high carbohydrate diet turns a normal liver (weighing 69 g) into a fatty one (695 g) in under two weeks (Gabarrou et al 1996). The potential to develop hepatic steatosis depends on the species of waterfowl and also varies with the genotype (Baéza et al 2013).

In an experiment by Babilé et al (1996), mulard ducks were force-fed for 10, 13 and 16 days, and at the end of each force-feeding period were released back into the rearer (grower) group. For the first few days they did not eat but drank copiously. The longer the force-feeding period, the longer it took for ducks to start eating again (8 to 15 days). They lost a lot of weight in the first week. The liver returned to its initial weight after 15 days following the end of force-feeding for groups force-fed for 10 and 13 days, and took 30 days to return to initial weight for those force-fed for 16 days. These results give an insight into the degree of insult from which the liver had to recover. Prolonging the force-feeding from 13 to 16 days has a disproportional effect on time to weight recovery (from 15 to 30 days), suggesting that 16 days of force-feeding brings the duck close to severe liver dysfunction and failure.

Bénard et al (2006) examined the effects of force-feeding on liver function, morphology and pathology. Ducks were force-fed for 2 weeks and then received normal *ad-libitum* feeding for 4 weeks. This cycle was performed 3 times, with force-fed birds compared with a control group fed *ad-libitum* throughout. Birds were kept in groups, and blood samples were taken at the end of every force-feeding or free-feeding cycle for the test birds and at the same time in the controls. A bromosulphophthalein (BSP) clearance test, a measure of the liver's ability to detoxify, was also performed. Birds were killed after 2, 6, 8, 12, 14 and 18 weeks and their livers examined.
While the weight of the non force-fed birds did not change significantly, the ducks that were force-fed put on weight (1.5 to 2 kg), but lost it during the 4 week non force-feeding period (1.4 to 2.3 kg). Gross hepatomegaly was noted in force-fed birds. Concentrations of liver enzymes lipase, alanine aminotransferase and aspartate aminotransferase rose significantly at the end of each force-feeding period, and after 4 weeks of normal feeding, returned to levels similar to those of the control group. In control birds after 2 weeks, hepatocytes had an average diameter of 7-10 µm whereas signs of steatosis were obvious in force-fed birds: hepatocyte diameter was 35-40 µm and the cell was full of fat vacuoles. After 3 cycles of force-feeding the liver structure was similar but 4 weeks later, most of the liver cells had an average diameter of 7-15 µm, similar to that of controls, and were no longer full of fat. BSP clearance, as measured by the area under the curve, was reduced in force-fed birds at 2 and 8 weeks, compared with controls, while it returned to normal after periods of free-feeding as well as after the third force-feeding cycle. The elimination half-life ($T_{½}$) of BSP was greatly prolonged at the end of each force-feeding period but returned to normal (values same as controls) after 4 weeks of free feeding.
The force-fed birds were kept on wire mesh floors and developed signs of tibio-tarsal arthritis as well as skin calluses on their feet; these lesions disappeared when birds were returned to straw litter for free feeding.
The authors conclude that, since animals were able to withstand three consecutive cycles of force-feeding, with four-week intervals of normal feeding, and that no pathology was found after these rest periods, force-feeding does not induce diet-related pathological changes as the steatosis is reversible, and therefore animal welfare is not adversely affected. However, survival after a problem does not mean that there was no problem. The reduction in the liver's ability to detoxify, as indicated by a slower BSP clearance, longer BSP half-life and raised liver enzymes (due to hepatocyte cell membrane damage allowing the enzymes to enter the blood), at the end of the force-feeding period, are all clear evidence of clinical pathology. This and various other data (SCAHAW 1998) show that the liver steatosis obtained by force-feeding induces an impairment of hepatic function, as demonstrated from morphometric, biochemical, histological and pharmacological aspects. While this was reversible in the studies described above, the reversibility of steatosis does not mean that the changes in the liver are not pathological. In the Babilé et al (1996) study, liver weight after 16 days of force-feeding took 30 days to reduce to normal, and in other studies the mortality of ducks increases when the force-feeding period is prolonged beyond a period of 15 days (SCAHAW 1998). The cause of death is likely to be liver

failure or its consequences such as necrosis and haemorrhage, septicaemia or respiratory disease, enteric disorders, cardiac myopathy and other causes (Guérin 2015).
There are other points made in the article by Bénard et al (1996) that require discussion. The force-feeding was performed on ducks housed in groups on the floor, and force-fed by one person seated on a stool within the pen. This force-feeding is not typical of current practice (Litt et al 2010), taking much longer, about 30 seconds. The birds were closely examined twice daily throughout the study, and after an initial 3-day period of agitation showed increasingly longer periods of rest between each force-feeding, as well as an increase in wing flapping. These behavioural changes are not explained. Increasingly longer periods of rest could be due to lethargy or abdominal discomfort, agitation and wing flapping due to pain, distress or fear. There is no mention of whether there was access to water troughs for head immersion and wet preening, and despite close examination twice daily, there is no description of the condition of the ducks, in particular of their face, eyes and nostrils (indicators of water access for head immersion, or site for injury). The findings of this study do not support the authors' conclusion that the force-feeding did not cause any suffering.

Carrière et al (2006a) adopted a different biochemical approach to evaluate the functional state of the liver, by looking for markers of liver inflammation and of steatosis. Peroxysome Proliferator-Activated Receptor (PPAR) is a protein receptor found within the cell nucleus; PPARs are active as transcription factors which control the expression of genes involved in cellular metabolism. There are three subtypes of these ligand-activated transcription factors (α, β/δ and γ); α and γ have important roles in the liver and in fatty tissue. PPARγ is involved in the control of lipid metabolism, stimulates adipocyte differentiation and is implicated in the development of the inflammatory process. PPARγ tends to have an anti-inflammatory effect.
This study looked at the expression of PPARγ during the development of liver steatosis in mulard ducks. This protein was present at a basal level in the liver and was over-expressed during force-feeding, and even more so at the end of force-feeding. The authors conclude that there is a need to determine whether or not there is expression of different sub-types of PPARγs, and if this expression is associated with the development of a non-pathological liver steatosis or of an inflammatory liver steatitis resulting from the feeding of a high-energy diet. We have not found additional published data on PPARs in ducks undergoing force-feeding.

Baéza et al (2013) suggest that few signs of liver inflammation develop during force-feeding because birds lack some cytokines which are secreted by the fatty tissue of mammals, such as TNF-α, and which are pro-inflammatory in some liver conditions in humans. However, it seems that TNF homologues do exist in birds (Varfolomeev and Ashkenazi 2004) so it would be worthwhile to examine their action in force-feeding.

We suggest that other physiological measures that could be used in the assessment of liver function in force-fed ducks include bile acids, ammonia, urea nitrogen, gamma glutamyltransferase, uric acid and coagulation factors (for example fibrinogen) in the blood and ketones in the blood or urine (Harr 2005). These measures are commonly used in other species. Because maize is not a balanced diet for ducks, other abnormalities may be present such as hormone imbalances or altered calcium to phosphate ratios leading to bone pathology (SCAHAW 1998).

Force-feeding

A major objection to the practice of foie gras production is to the consequences of forcing food into the animals. The animal no longer has autonomy when it comes to what, when and how much it will eat. It is not allowed to feed spontaneously or show a food preference, and is force-fed increasingly large amounts of food, all of which are much greater than it would normally eat. The diet itself is formulated for maximum growth and fat deposition, especially in the liver but also subcutaneously as 'magret'. The insertion of a feeding tube to deliver the ration, in most cases in an automated manner, has the potential to cause injury to the animal's bill, face, neck and upper digestive tract. Birds used in foie gras production are the only farmed species that is not allowed to feed by expressing normal feeding behaviour.

Ducks are fed considerably more during the force-feeding period than they would eat voluntarily, and they receive this food without having the possibility to forage in a species-specific manner. Each duck will be motivated to perform normal foraging activities, such as searching for food, pecking, nibbling, dabbling, up-ending and swallowing, even if it is force-fed. Such a need to forage for food is not met during force-feeding (SCAHAW 1998).

Several behavioural characteristics of mulard ducks can be recognised. On the one hand they are fearful of humans and nervous, or 'sensitive to the environment' (Laborde and Voisin 2013), while on the other hand they are gregarious and sociable towards conspecifics (Guémené et al 2006b). While the last two characteristics indicate that group-housing is likely to be enriching, the first two make mulard ducks particularly unsuitable for force-feeding because, fearful of humans and nervous, they struggle, try to escape or retreat to the back of the cage.

Behavioural responses

Compared with physical and physiological effects, there is an even greater lack of published data on the behavioural responses to force-feeding, both during the procedure itself and at other times, for example immediately beforehand when the ducks anticipate a potentially unpleasant experience, and afterwards when the duck has to assimilate a large amount of food that has been forcibly inserted into its oesophagus. When behavioural responses are described, their interpretation and significance from a welfare perspective is sometimes lacking or incomplete.

The gag or pharyngeal reflex is a reflex contraction of the back of the throat, evoked by touching the roof of the mouth, the back of the tongue, the area around the tonsils or the back of the throat. There is a contraction of both sides of the posterior oral and pharyngeal musculature, and humans report that this is an unpleasant experience (see http://www.neuroanatomy.wisc.edu/virtualbrain/BrainStem/09NA.html).
The reflex helps to prevent material from entering the throat, except as part of normal swallowing, and protects against choking and aspiration. Some people have a hypersensitive reflex while others can learn to inhibit it (for example, sword swallowers).
There is controversy as to whether the reflex is present in ducks; we agree with SCAHAW (1998) that it is. Unlike some birds such as pelicans and storks, mulard

ducks consume food by dabbling and sieving and do not swallow large food items. There is no reason why the pharyngeal reflex would be absent in these ducks. Initially, force-feeding stimulates this reflex but after a certain time it stops. The adaptation time required for the gag reflex to be extinguished, and how the duck is affected by this, are not known. For example, some birds shake their head vigorously after force-feeding but the specific cause of this is not known (Carrière et al 2006b). Head-shaking is normally an indicator of an aversive event and is also noted when birds are deprived of access to open water (Rodenburg et al 2005).

The behaviour of mulard ducks following force-feeding, during the hour after the second, twelfth and twenty-fourth meal (three time periods), was compared with mulard ducks that were kept in the same conditions but not handled or force-fed (Carrière et al 2006b). The ducks were not kept in typical production cages, as they were group-housed in cages (3 ducks per cage with 80 cm X 80 cm floor surface area). These cages were large enough to allow birds to stretch and spread their wings, so they could show a wider range of behaviours than ducks kept in standard individual cages. The test birds were force-fed twice daily for 13 days (the amount fed at each meal, and whether the amount increased day by day, are not specified). The control ducks had *ad-libitum* access to food, which was provided every morning at the same time as the test ducks were force-fed. The behaviour of the control ducks was video-recorded the day after the recording of the test ducks.

The force-fed ducks spent more time lying down, and walked less frequently and for a shorter time than control ducks. There was a trend towards spending less 'time standing immobile', and an interaction with time period for the behaviours 'time spent standing immobile' and 'time spent lying'. The authors explain these results by the physical effects of the ducks' weight gain on posture and movement; birds gain a lot of weight during the force-feeding period and their mobility is greatly reduced. We argue that this has consequences with regard to the ducks' welfare. The excess weight (caused by force-feeding) can reduce the animal's mobility by a number of mechanisms including pressure from an enlarged liver on limbs, reduced respiratory capability and pain. Lack of mobility is likely to lead to further consequences that reduce welfare such as poor muscle strength, bone fractures, skin lesions and altered social interactions with conspecifics. When birds are kept in restrictive environments where they cannot move freely, recognising mobility problems becomes difficult.

Over the force-feeding period, the test birds spent less time with their head at rest while this behaviour in control birds did not diminish over the same period. After the twenty-fourth meal, hardly any time was spent with the head in the rest position. This may have resulted from the animal's excess weight, from food in the oesophagus or from discomfort in the head and neck region and would prevent the bird from resting fully.

Grooming and preening behaviour occurred less often, and for a shorter time, in the force-fed birds (evident from the first time period). After the last time period, force-fed birds spread their wings less and over time they shook their tail less frequently than controls. There was a trend for the force-fed birds to groom their conspecifics less than controls and for this behaviour to decrease over time, suggesting a decrease in social interactions. However, there was no evidence of increased aggression between force-fed ducks.

Most intensive farms for foie gras production have air ventilation systems to keep ambient temperatures relatively low, in an attempt to reduce thermal stress in the birds. Nevertheless, the force-fed ducks spent a lot of time panting. This behaviour was not evident in the control ducks at any time, and not in test ducks after the second meal. After the twelfth meal 5 out of 9 ducks panted, and after the twenty-fourth all panted in the hour after force-feeding. Panting to aid evaporative cooling is part of the thermoregulatory response to the ingestion of large amounts of high-energy food, as is immersion of the face and, by wet preening, the body in water. The birds had access to water but it is not clear whether the access was to water troughs, showers, baths or nipple drinkers; it seems that water was only available for drinking. The test birds had to spend a significant proportion of their time in behaviour to restore thermal homeostasis that was disrupted as a result of force-feeding, something the control birds fed *ad-libitum* did not have to do. In addition, the apparent lack of adequate access to water, which would have helped them cope with this disruption, further reduced their welfare.

Force-fed birds shook their head more than controls, especially after the first force-fed meal but also after subsequent meals. The authors suggest that this may be a reaction to handling by the force-feeder, or to the introduction of a large amount of food into the oesophagus. Head-shaking is also seen when birds are deprived of access to open water (Rodenburg et al 2005), and may be evidence of stimulation of the gag reflex (see above). Self-grooming, preening and wing-stretching are all behaviours generally associated with good welfare in birds (Rodenburg et al 2005). The time spent performing these behaviours was less in force-fed compared with control birds and decreased over time, further evidence for poor welfare in force-fed birds.

This study was limited to examining the behaviour of birds for one hour after force-feeding; examination of further time periods during the day would have been useful. In addition, there may have been an effect of handling, separate from the effect of force-feeding, on the behaviour of the test birds but this was not explored as controls were not handled prior to feeding.

For comparison, the time budget of commercially-reared Pekin ducks at 41 days was: 1.5% of the time feeding, 6.7% drinking, 4.2% rooting and 15.5% dry preening (Jones and Dawkins 2010b). They spent 43.5% of time fairly inactive, either remaining stationary but alert, resting, settling to rest or panting (12% of time, and 6% at 23 days). Most of the rest of the time (17%) they performed comfort behaviours such as leg, wing or head stretches and shaking their body, wing flapping, wing lifting, and small mandibular movements. On average 4.6% of their time was spent walking and 1.8% wet preening.

The behavioural responses to force-feeding were also examined in ducks by Faure et al (1998, 2001). Two types of experiment were performed. In the first, ducks were trained to be fed in a pen 8 m away from their rearing pen and were then force-fed in the same feeding pen. The hypothesis was that if force-feeding caused aversion, the animals would not spontaneously leave their rearing pen or go into the test pen.

At 11 weeks of age ducks were kept in 8 groups of 15 until the end of the experiment. During the 14-day training period, they were trained to go spontaneously, once a day (in the morning), from the rearing pen to the test pen where they received their daily food ration (200 g of cooked maize). During the first 3 days of training, the experimenter pushed out the ducks. After this initial training period, whenever the ducks did not move spontaneously after the door opened, the observer entered the pen after an interval of 30 s and pushed the ducks towards the door. The same procedure was repeated if the ducks did not enter the test pen within the required interval of 30 s. After all the food had been eaten (60 to 90 min), the door of the test pen was opened and the same procedure repeated. After two weeks of training to go spontaneously from the rearing to the test pen, where they received their daily meal, the control group followed the same procedure whereas the test group received the same quantity

(200 g) of cooked maize by force-feeding for a period of 10 days.

During the test period, control animals spontaneously left the rearing pen in about half of the tests, whereas none of the force-fed groups did. The control groups also spontaneously entered the test pen during each test, whereas only about a half of the force-fed groups did. These results indicate that the ducks found the force-feeding procedure aversive and were reluctant to enter the pen where they were force-fed. Some problems were encountered with the training of the birds because on days 13 and 14 the usual experimenter was absent and was replaced by an unfamiliar person, which produced a level of avoidance comparable to the force-feeding itself.

It is not clear why the amount of food fed to the ducks throughout the 10 day experimental period stayed the same and was given just once daily, as in the commercial situation the amount of food force-fed to the ducks would increase from day to day, and would be given twice daily. Force-fed ducks normally receive 250 g of food on the first day, rising to 900 g by the tenth day (Guémené et al 2007). Feeding increasing amounts of food, and force-feeding twice daily, is likely to increase the strength of aversion shown to force-feeding.

In this force-feeding study in which aversion responses were recorded, the ducks were subjected to possible positive and negative stimuli simultaneously and the net effect measured. The occasion during the day when feeding occurred was likely to be positive and the procedures of force-feeding were likely to have negative components. It may also be that any aversion responses tended to have negative consequences so the birds learned not to show them.

In the second experiment by Faure et al (2001), the flight distances of ducks from the person who performed the force-feeding and from an unknown observer were measured for ducks housed in individual cages. Flight distance was the distance between the person and the duck's cage, at the time when the duck withdrew its head into the cage as the person approached it. Tests were performed 2 to 6 hours after the force-fed meal on days 3, 7, 9 and 11.

On day 3 the flight distances were similar. On day 7 and day 9 ducks avoided the unknown person more than the force-feeder and their avoidance of the force-feeder decreased during the force-feeding period. The authors conclude that there was no evidence of an aversion for the person who performed the force-feeding.

However, examination of the graph provided shows that the avoidance of the unfamiliar person decreased after day 7 at a greater rate than for the force-feeder, and was not greater than for the force-feeder by day 11. It is possible that the decrease in flight distance for the force-feeder between days 3 and 7 was an effect of familiarity rather than evidence of a lack of aversion, because the force-feeder would have been feeding the birds on days 4, 5 and 6, when the approach test did not take place and the birds were not exposed to the unfamiliar person. However, after days 7 and 9 the unfamiliar person would now be a familiar non force-feeder so the flight distance decreased even more rapidly than for the force-feeder, suggesting that, with both persons now considered familiar, there was aversion to the force-feeder because flight distance between days 9 and 11 decreased more slowly for the force-feeder than for the non force-feeder. Repeating this experiment using two persons of equal familiarity, with one doing the force-feeding and the other not, would be useful. Since the birds were confined to individual cages with no space to escape or hide, the range of aversion behaviours the ducks could show was very limited. Withdrawal of the head into the cage as a person approached may not be the best measure of aversion, especially when it is used as the sole measure. In fact such a response could cause greater problems for the bird. Withdrawal of the head when the person wants to put the tube in the oesophagus could lead to rough handling or other punitive actions by the person feeding. Another result of head withdrawal that would be negative for the duck could be that the process lasted longer. Ducks could learn not to withdraw their heads for either of these reasons. Hence this is a poorly-controlled experiment with alternative explanations for the results. It does not demonstrate that force-feeding is not aversive to ducks.

Physiological responses

Guémené et al (2001) examined the effects of the force-feeding procedure and its different components (handling, intubation) on various physiological indicators of acute and chronic stress in male mulard ducks before and during a 12-day force-feeding period. The highest concentration of corticosterone were measured after injection of an ACTH agonist, during the pre-experimental period when the ducks were still housed in group floor pens, and at the time of transfer from pens to individual cages. The group housed ducks had to be caught before being sampled, which is likely to have caused stress and raised corticosterone levels. During the force-feeding period, corticosterone measured before and after force-feeding did not increase significantly although there was a non-significant trend towards an increase on some days. The different components of force-feeding, including handling and intubation, force-feeding with a standard or a large amount of food had no significant effect upon corticosterone concentrations. There was no indication from ACTH agonist challenge either of a change in adrenal sensitivity or a change in its responsiveness. The authors conclude that there was no significant indication that force-feeding was perceived as an acute or chronic stress by male mulard ducks, in the experimental conditions. They acknowledge, however, that it remains to be shown that the ducks' adrenocorticotrophic axis is responsive to acute stressors.
There were additional results that indicate that further research in this area is required. For example, very high corticosterone concentrations were observed for all experimental groups while the ducks were still in group pens and not yet force-fed. There was a significant decrease in bodyweight for control, handled and intubated ducks over the 2 week period, which may have been the consequence of being housed in individual cages. The heterocyte-lymphocyte ratio (sometimes a measure of more chronic stress) measured before and at the end of the force-feeding period did not differ significantly, although there was a trend for the ratios to increase with increasing physical handling (from controls to intubation to mild and full force-feeding). The results of Guémené et al (2001) regarding corticosterone levels before and after force-feeding are not in agreement with those of Mirabito et al (2002c). Guémené et al (2001) found that corticosterone measured before and after force-feeding did not increase significantly though there was a non-significant trend towards an increase on some days. However, Mirabito et al (2002c) found that force-feeding caused significant increases in corticosterone in some groups of ducks on some days.

Another study by Guémené et al (2006a) sought to investigate further the HPA axis functionality in male mulard ducks and to examine for possible interactions between force-feeding practice and rearing environment on behavioural and physiological indicators of stress and poor welfare. This publication is complex, and consists of three separate experiments: the first two measured plasma corticosterone levels and the third studied behaviour patterns. In the first experiment, birds were kept in

individual cages and half were force-fed while half were not. Within each group some birds were subjected to further treatment, being placed on the floor and tightly constrained in a net for 10 minutes after force-feeding, either on the 8th and 13th day or twice daily throughout the experimental period. In the second experiment, three housing environments were compared: slatted floor group pens, group cages and individual cages. In the third experiment, ducks were kept in three housing environments (as described in experiment 2) and their behaviour recorded.
The results of the first two experiments confirmed those from previous studies (Guémené et al 2001). When in individual cages the majority of male mulard ducks did not respond by a significant increase in corticosterone levels after force-feeding, even on its first occurrence. Force-fed and non force-fed ducks were, however, sensitive to physical treatments such as a tight constraint in a net. The response to physical treatments reduced with time, which may have indicated habituation. For birds kept in group pens or cages, the capture and immobilisation before force-feeding may have been a cause of repeated stress.

Flament et al (2012) also found that corticosterone levels in force-fed ducks did not increase during the force-feeding period. However, triglyceride and aspartate aminotransferase (AST) levels in plasma increased during force-feeding and until slaughter, as did levels of uric acid in plasma. The authors explain raised uric acid levels as being most likely due to the oxidative stress associated with force-feeding.

In contrast, in a recent study on force-feeding and stress in muscovy ducks blood corticosterone levels of force-fed ducks rose while those of controls did not and ducks that were force-fed spent more time panting than controls (Mohammed et al 2014). It is not clear whether a lighting schedule of 23 hours light and 1 hour darkness was used; this schedule may affect the ducks' behaviour and physiology.

A complicating factor in the interpretation of the results of Guémené and others is that the birds were receiving food and this can suppress any increase in glucocorticoids. A further factor is that the birds had previous experience of being force-fed and are likely to have learned that the increased activity, associated with greater plasma corticosterone concentration, is counter-productive. A bird which shows an excited response is more likely to be hurt by the force-feeding process. Hence, any birds which can suppress such a response are likely to have less pain and other poor welfare than birds that react actively. In the same way, human prisoners who showed a passive response when at risk of being caused pain, survived better than those who reacted.

In summary, from the studies presented above we can conclude that levels of blood corticosterone are a poor indicator of welfare in mulard ducks (JAVMA 2014). They must be considered in conjunction with other welfare indicators such as health, pathology, other physiological measures, behaviour and other indicators of mental state (Broom and Johnson 2000).

Thermal stress and panting

Due to the large amount of food that is force-fed, ducks are susceptible to thermal stress which causes panting in order to disperse the extra heat generated from digestion. Force-fed birds may spend large amounts of time, standing or lying down,

performing this behaviour and unable to do anything else (like preening or resting). This thermal stress makes the duck very prone to environmental heat stress, which adds further to their discomfort, reduces food digestibility and increases mortality. Nutritional supplements containing electrolytes and anti-oxidants have been developed to mitigate these effects (Mathiaud et al 2013).
Immersion in water is another homeostatic mechanism for thermoregulation in birds. If water for immersion is not available then heat stress becomes a risk (Rodenburg et al 2005) (see Housing).

Production of foie gras without force-feeding

Researchers are keen to find a way of producing foie gras without the need to force-feed (Guy et al 2007). The aim is to stimulate ducks and geese to over-eat voluntarily to a degree that is sufficient to lead to hepatic steatosis. The options they present are:

1. Manipulating feeding behaviour
   Over-eating can be stimulated by previous restriction followed by *ad-libitum* provision of food, and is affected by photoperiod and other climatic conditions. It is not a long-lasting effect and results are variable.
2. Surgery
   Methods to destroy the satiety centre in the brain of geese have given varying results. For ethical reasons this approach is unacceptable.
3. Pharmacology
   It may be possible to induce transient over-eating by passive or active immunization against the hormone leptin, which regulates appetite. There has even been a study looking at the use of the compound arsenic to induce fatty liver in mule ducks (Chen and Chiout 2001). These un-natural processes are unlikely to be acceptable to the consumer.
4. Genetics
   It may be possible to select for individuals that over-eat. However, it is likely that the birds will fatten excessively and this would have a negative effect on reproductive success of the parents.
5. Other
   A completely different approach would be firstly to interfere with Very Low Density Lipoprotein transport of newly synthesized lipids from the liver to peripheral tissues and, secondly, to limit the storage of lipids in peripheral tissues (Guy et al 2007). However, methods to do this have not been developed.

Attempts have been made to stimulate spontaneous over-eating in geese by manipulating day length and feeding regimes (usually restriction followed by *ad-libitum* feeding) (Fernandez et al 2013, Guy et al 2013, Bonnefont et al 2015, Fernandez et al 2015). In a study by Guy et al (2013), male Greylag Landaise geese were fed *ad-libitum* from birth to 5 weeks of age, and then were food-restricted until 20 weeks when they were again fed *ad-libitum* until death. The diet from 20 weeks onwards consisted of maize. Photoperiod is a major environmental factor controlling migration and the pre-migratory fattening process in birds. From 21 to 23 weeks, the daylight duration was progressively reduced from 10 to 7 h and kept at 7 h until the end of the experiment (week 31). Thirty birds were slaughtered at 19, 23, 25, 27, 29, and 31 weeks. During the first 2 weeks after maize delivery, the average consumption

rose up to 600 g/bird/d and decreased slowly thereafter to reach 270 g at week 31. Liver weight increased from 95 g (week 19) to 514 g (week 31), and most of these changes were due to the increase in lipid content from 6 to 50% of liver weight. There was no mortality during the experimental period. Histology indicated that fat accumulated in the hepatocytes, which increased in size without any sign of inflammation or degeneration. It seems that, under specific conditions of photoperiod and feeding, geese are able to initiate spontaneous liver steatosis. However, the variability in the response was high; at week 31, the coefficient of variation for liver weight was 45%.
In a similar experiment by Bonnefont et al (2015), a high mortality rate (20%) was noted in geese between 133 (19 weeks) and 217 days (31 weeks) on *ad-libitum feeding*. This was most likely due to the very early and rapid development of liver steatosis. There was also a great variation in response. In another study, when feeding was restricted and then allowed *ad-libitum* for longer, Fernandez et al (2013) noted that geese kept in individual cages ate 13% less food than those kept in groups, underlining the importance of social interactions on food intake. In this study, the period of feeding was prolonged but performance did not improve; in fact, geese started dying after 32 weeks.

These experiments indicate that, in certain conditions, geese are able to develop hepatic steatosis without force-feeding, offering the possibility of foie gras production in this species without the need to force-feed. However, these alternative methods currently have negative impacts on the environment (Brachet et al 2015). Indicators of environmental impact were estimated and were greater for non force-fed than force-fed geese. This was mainly due to a greater consumption of food despite lower liver weights, longer production times, larger amounts of animal waste produced and overall lower productivity. In addition, it seems that the liver produced by these alternative methods is less liked by some consumers (Fernandez et al 2015).

A farmer from Extremadura, Spain, produces foie gras from geese under the label ‘Sousa & Labourdette’. These geese are free-range and feed freely on a range of foods available on the farm. The product is described as ‘natural’ and ‘ethical’. It is produced in small amounts at a high cost and is aimed at a niche market, particularly restaurants (see http://www.sousa-labourdette.com/). The French company Labeyrie makes products containing the liver and fat from ducks and geese that have not been force-fed, called Foie Fin.

Faux Gras® by GAIA is a Belgian plant-based product that is sold in most supermarkets in Belgium during the Christmas and New Year period (see http://fauxgras.be/language-choice/). Faux Gras™ is an American product made of toasted walnuts, lentils and onions and is marketed as a humane vegan alternative to foie gras (see http://www.regalvegan.com/site/products/faux-gras/).

Risks of foie gras consumption to humans

There are concerns that the consumption of foie gras may have negative effects on humans. Solomon et al (2007) found that duck- or goose-derived foie gras contained amyloid protein and raised the possibility that this protein could hasten the development of amyloidosis in a susceptible population. Their abstract is as follows:
“The human cerebral and systemic amyloidoses and prion-associated spongiform encephalopathies are acquired or inherited protein folding disorders in which

normally soluble proteins or peptides are converted into fibrillar aggregates. This is a nucleation-dependent process that can be initiated or accelerated by fibril seeds formed from homologous or heterologous amyloidogenic precursors that serve as an amyloid enhancing factor (AEF), and has pathogenic significance in that disease may be transmitted by oral ingestion or parenteral administration of these conformationally altered components. Except for infected brain tissue, specific dietary sources of AEF have not been identified.
Here we report that commercially available duck- or goose-derived foie gras contains bi-refringent congophilic fibrillar material composed of serum amyloid A-related protein that acted as a potent AEF in a transgenic murine model of secondary (amyloid A protein) amyloidosis. When such mice were injected with or fed amyloid extracted from foie gras, the animals developed extensive systemic pathological deposits. These experimental data provide evidence that an amyloid-containing food product hastened the development of amyloid protein A amyloidosis in a susceptible population.
On this basis, we posit that this and perhaps other forms of amyloidosis may be transmissible, akin to the infectious nature of prion-related illnesses."

A more recent publication (Greger 2008) has the following abstract:
"The demonstration of oral Amyloid-A (AA) fibril transmissibility has raised food safety questions about the consumption of amyloidotic viscera. In a presumed prion-like mechanism, amyloid fibrils have been shown to trigger and accelerate the development of AA amyloidosis in rodent models.
The finding of amyloid fibrils in edible avian and mammalian food animal tissues, combined with the inability of cooking temperatures to eliminate their amyloidogenic potential, has led to concerns that products such as pâté de foie gras may activate a reactive systemic amyloidosis in susceptible consumers.
Given the ability of amyloid fibrils to cross-seed the formation of chemically heterologous fibrils, the speculative etiologic role of dietary amyloid in other disease processes involving amyloid formation such as Alzheimer's disease and Type II Diabetes is also discussed. "

Housing

Housing in groups

Until recently, the majority of production systems placed ducks in individual cages during the force-feeding period rather than in group pens or cages. The main advantages to the producer are that the ducks could be force-fed rapidly one after the other, without the feeder having to catch them, and that "they always remain in the right position" (Guémené and Guy 2004). Individual cages were small and greatly restricted the bird's movements; they did not allow the bird to turn around, stretch and flap its wings, stretch to its full vertical height or horizontal length or show more than a minimal behavioural repertoire. The degree of restriction increased as the bird grew fatter during the force-feeding period. Using a pneumatic or hydraulic force-feeding pipe, up to 400 individually caged ducks could be force-fed by one person per hour.

After January 2016, individual caging of ducks for foie gras production will be illegal in France, and should be replaced by group (collective) housing. Ducks will have to be housed in groups of at least 3 birds. The Council of Europe recommendations (1999) concerning Muscovy ducks (*Cairina moschata*) and hybrids of Muscovy and domestic ducks (*Anas platyrhynchos*) state that housing systems for ducks shall allow the birds to:
Article 10.7
- stand with a normal posture,
- turn around without difficulty,
- defaecate showing normal movements,
- flap the wings,
- show normal preening movements,
- perform normal social interactions,
- carry out normal feeding and drinking movements.

Group housing allows social interactions between birds and gives them more space as a group. The individual bird should be able to turn around and spread its wings fully, and stretch vertically to its full height. Factors that affect welfare in group housing include group size, stocking density, social interactions, type of flooring used, use of litter or bedding material, access to water for drinking, and the provision of water for bathing, or at least full immersion of the head. Management of the air space and ventilation, maintaining cleanliness and controlling disease, and ensuring homogeneity of groups are also important. Potential undesirable effects of group housing include increased aggression between birds, difficulty in maintaining cleanliness (especially in larger groups), competition at water sources and increased stress and fear when the birds are caught for force-feeding. Guémené et al (2002, 2006a) found that the capture and immobilisation of group-housed birds for force-feeding can be a cause of repeated stress.

Due to the impending legislative change, over recent years research has focussed on alternatives to individual cages. Mirabito et al (2006) compared ducks kept in groups (from 3 to 8 per group) to those in individual cages. The study was done in two stages; in the first the group cages provided birds with a floor area of 2000 cm^2 to 2142 cm^2 each, and in the second between 1500 cm^2 and 1875 cm^2 each. All 3 types

of group cage had a movable front wall device to restrain ducks ('peigne de contention') and two had a movable back wall. When the birds were slaughtered, variables such as mortality during the force-feeding period, final body weight, 'magret', liver and thigh weight, lesions on the carcasses such as claw scratches and keel injuries, thigh haematomas, fractures or fissures of the humeral head and general cleanliness of the birds were recorded. The terms 'smaller' and 'larger' refer to surface area per bird, and not to total group size unless specified.
Mortality in group cages was 6.2 % in the first stage, and 3.4 % in the second stage when there were smaller cages with fewer ducks and better sanitary conditions. The highest mortality occurred in the largest cage with the most ducks, in the first stage where there were problems with maintaining cleanliness. In terms of performance outcomes, group housing (and surface area of 2000 cm^2) had a positive effect on 'magret' weight but not on other measures such as liver or body weight. For other variables such as carcass lesions and general cleanliness, there were differences between individual and group cages on the one hand, and within group cages on the other. Lesions on the back and scratches occurred more frequently in groups than in individually housed ducks, as would be expected, whereas the opposite was true for humeral head lesions, perhaps a reflection of reduced activity and subsequent bone weakness.

Previous work on group housing has examined the effect of floor space and group size on production (mortality, liver weight, carcass and thigh weight, final body weight), behaviour and blood corticosterone (Mirabito et al 2002a,b,c). In general, the best production results were obtained when ducks had 2000 cm^2 of floor area each, and larger groups (9 ducks) had higher mortality and poorer cleanliness (Mirabito et al 2002a). However, birds kept at the highest stocking density in the smallest group had more humeral lesions at slaughter, perhaps again a reflection of reduced activity and subsequent bone weakness. Surface area per bird was the main factor that influenced behaviour, with birds kept at 1000 cm^2 each moving less and stretching their wings less frequently than birds kept at 1500 or 2000 cm^2 density (Mirabito et al 2002b). For the latter behaviour, there appeared to be an interaction between group size and stocking density, as frequency of wing-stretching was affected by the total amount of space available.
The effects of group size (3, 6 or 9 ducks) and surface area per bird (1000, 1500 and 2000 cm^2) on blood corticosterone before and after force-feeding and on the HPA axis was explored, and compared with birds housed individually (Mirabito et al 2002c). There was great variability in resting corticosterone levels, and force-feeding caused significant increases in corticosterone in some groups on some days, so it was not possible to draw meaningful conclusions regarding the effects of different housing conditions on blood levels of corticosterone. Increases were noted for ducks housed individually after the 1st and 11th meal, findings which are not in agreement with those of Guémené et al (2001). There was no evidence of abnormalities in sensitivity or reactivity of the HPA axis, except for some unusual results obtained for the group of 6 ducks kept at 1500 cm^2 stocking density.

Between 2007 and 2009, trials of group versus individual housing of ducks were performed by Litt (2010). One model of group housing was compared with two models of individual housing, using the following criteria: product quality (liver and 'magret'), the condition of the carcass immediately after slaughter, work conditions for the force-feeder and the use of water for cleaning. The focus was largely on production outcomes rather than on welfare.

While birds were fed the same amount, group housing led to a decrease in liver weight (-77 g on average), an increase of 55% in the time taken to perform the force-feeding (from 5.6 seconds to 8.7 seconds per bird), and a 34% increase in the amount of water used in cleaning (although this figure has been reduced in more recent models). There was a slight increase in the weight of the 'magret' (+ 4 g), a finding also noted by Mirabito et al (2002a). In group-housed birds there was also an increase in liver defects at slaughter (+15%) and fewer haematomas but more scratch lesions on the carcasses; there were more scratches on the thighs than on the back. Breast lesions were more severe and more frequent when birds were kept on a plastic rather than a steel mesh floor.
More recent models of group housing have been modified, particularly with regard to the containment (restraint) of birds and the work conditions of force-feeders during feeding and cleaning.

Housing of foie gras ducks in Belgium

In a Royal Decree of December 2010, Belgium adopted modifications to the Royal Decree of April 1994 (which arose from legislation of August 1986 regarding the welfare and protection of animals, article 36,10). These forbid the use of individual cages, require group housing with at least three birds per cage or housing in larger groups. They have been implemented throughout Belgium and individual caging does not occur.
The recommendations state, for example, that the period of force-feeding in ducks must not last longer than 14 days, and that the water troughs should allow birds to immerse their head (dimensions are given: at least 75 mm deep and 65 mm wide). There should be no fewer than three ducks per cage, with each having at least 1200 cm^2 of surface area. With larger groups, there should be no more than six ducks per m^2. There is no mention of the provision of litter or bedding material, or the use of a restraint method during force-feeding. In general, the recommendations are largely based on the existing French scientific literature, what is practised in France, and EU guidelines.
At the end of 2012 force-feeding of ducks was practised in 11 farms in Wallonia and one in Flanders (Marlier and Bauwens 2012). Six used group cages and six kept groups in pens on the floor ('parc collectif'). Litter was provided in four of them, while two had a wire mesh floor. Usually litter consisted of whole wheat straw added twice daily during feeding time. This litter would provide some degree of enrichment, by creating a more comfortable floor surface and as substratum for manipulation and exploration.
Foie gras production in Belgium is regulated and controlled by the public authorities (see http://www.eurofoiegras.com/en/page/initiatives_p139/). The Belgian Federal Agency for the Safety of the Food Chain (AFSCA) certifies production sites.

Design of group cage to restrain ducks

A containment (restraint) method has been developed by researchers and producers, to overcome the problem of birds trying to escape, struggling or retreating to the back of the group cage and hence being difficult to force-feed. A movable back wall pushes the birds towards the front. As the birds collect at the front, the front vertical wall descends back over them ('peigne de contention') and prevents them escaping or moving much (see http://www.eyhartzea.com for an illustration; on this farm with this system, approximately 100 birds can be force-fed in under 20 minutes).

Group-housed birds may be more susceptible to injury from handling, getting caught in the cage's containment mechanism, or restrained in an uncomfortable position for a long time, (up to 30 minutes) as the force-feeder works up one row of cages and back down the other before releasing the containment mechanism. Because birds immobilised by the movable grids may be facing any direction, the force-feeder must be able to insert the feeding tube from any angle (Cepso 2013). There is likely to increase the risk of injury to the bird's face, upper digestive tract or body, especially if it struggles and resists or if other birds get in the way. This makes it more difficult, and takes longer, for the force-feeder to carry out their task, especially with larger groups (Mirabito et al 2002a, Litt 2010). The force-feeder is unable to develop a steady rhythm, working their way uninterrupted along a row of cages as was possible with individual caging, and this further increases the risk of injury to the birds.

The brochure by the agricultural group Cepso Chambagri "Le logement collectif pour le gavage des canards", produced in 2013, illustrates 12 different types of cages and provides a summary table which compares all the cage systems with regard to density, floor space per bird, and other parameters (Cepso 2013). Ten out of 12 cages can contain between 4 and 6 birds with the remaining 2 having a capacity of up to 10 birds. Recommended cage floor surface area is 4000 cm^2 for 3 ducks, 5000 cm^2 for 4 and at least 1200 cm^2 surface area per bird (the equivalent of 2 size A4 sheets of paper), for 5 ducks or more. The cage should be tall enough for the bird to stretch fully to its vertical height; there is no roof. Ten of the systems have a movable back wall, and all but one have a front vertical wall that can move back and down to restrain the birds ('peigne de contention'). Based on available published studies, the choice of cage floor surface area per bird seems to be a compromise between economics (1000-1200 cm^2) and duck comfort (1500-2000 cm^2). Most are on the smaller side, with a surface area per bird of 1200 cm^2 to 1300 cm^2. To our knowledge, there are no published studies on the social interactions between birds, optimal group size, behaviour time budgets or approaches to improve the cage environment.

Flooring and provision of litter

Force-fed ducks are usually kept on a mesh floor ('caillebotis') made of some type of steel (galvanised or stainless) and less commonly of plastic. They gain weight very quickly and their liver expands, which causes problems with mobility due to excessive weight on joints and loss of balance (SCAHAW 1998). They become inactive and spend more time resting on a bare surface, as litter is not provided. This sequence of events is likely to lead to a worsening of contact dermatitis (footpad, hock and breast lesions), which is already present at the starter and grower stages of foie gras production (Litt et al 2015c). Conditions during these stages are relevant to the development and course of the disease. Contact dermatitis is common, develops early during the production process, worsens with age and is a cause of pain and disability. The reasons for this are not obvious; the condition is already of moderate to marked severity when birds are ready for force-feeding. It is not clear whether lesions improve, worsen (Litt et al 2015b) or stay the same (Litt et al 2015a,c) during force-feeding. Bénard et al (2006) noted that force-fed birds kept on wire mesh floors developed signs of tibio-tarsal arthritis as well as skin calluses on their feet. These lesions disappeared when birds were returned to straw litter for free feeding.

Many environmental factors have been associated with the development of contact dermatitis; why it occurs in some flocks and not in others is not fully understood. It is recognised that a major contributing factor, particularly at the onset, is the type of litter, or ground quality if litter is not provided. Damage occurs to the skin surfaces that have prolonged contact with the litter, usually starting with the footpad and toes, then the rear surface of the hock and, when severe, the breast area. While high moisture litter is sufficient to cause the condition, litter depth, ammonia levels, climatic conditions, condensation, ventilation, stocking density, rearing system, leg weakness, ground quality and diet are also recognised as causative factors (Haslam et al 2007, Bassett 2009, Shepherd and Fairchild 2010, Hepworth et al 2011). Methionine may be a contributing cause, and maize is methionine-deficient (Bassett 2009). Imbalances in other amino acids (such as choline) and vitamins may also be involved.

EU recommendations (Council of Europe 1999) concerning Muscovy ducks (*Cairina moschata*) and hybrids of Muscovy and domestic ducks (*Anas platyrhynchos*) state:

Article 10
6. Where ducks are housed, floors shall be of a suitable design and material and not cause discomfort, distress or injury to the birds. The floor shall include an area sufficient to enable all birds to rest simultaneously and covered with an appropriate bedding material

Article 11
4. Adequate litter shall be provided and maintained, as far as possible, in a dry, friable state in order to help the birds to keep themselves clean and to enrich the environment

Despite these recommendations, currently the standard group cage used for foie gras production lacks an area where ducks can rest together, and there is no bedding material or litter to ensure their comfort and cleanliness, and to provide substratum for foraging and exploratory behaviours. The cage is not enriched beyond the provision of water troughs and of conspecifics. The floor consists of a relatively hard, bare surface which may worsen the birds' condition, having already developed contact dermatitis in previous stages of production. The group cage is relatively barren and has not 'addressed the animal welfare issue' as suggested by some sources. In many ways it resembles the conventional battery cage for laying hens, a design banned in the EU since January 2012 on welfare grounds, one difference being that the ducks cannot feed for themselves.

Access to water

Ducks spend considerable time performing complex preening behaviours (Rodenburg et al 2005). After feeding followed by bathing, ducks carry out a variety of shaking movements to remove water. Cleaning movements are used to remove foreign bodies and an elaborate sequence is carried out to distribute oil on the feathers from the uropygial gland above the tail. This is necessary for waterproofing and heat regulation. Preening is often followed by sleeping for a short period, and the sequence of feeding, bathing, preening and sleeping may be repeated a number of times during the day. Important elements of bathing are the immersion of the head and wings, and shaking water from these over the body.

EU recommendations (Council of Europe 1999) concerning Muscovy ducks (*Cairina moschata*) and hybrids of Muscovy and domestic ducks (*Anas platyrhynchos*) state:

Article 10
2. Access to an outside run and water for bathing is necessary for ducks, as water birds, to fulfill their biological requirements. Where such access is not possible, the ducks must be provided with water facilities sufficient in number and so designed to allow water to cover the head and be taken up by the beak so that the duck can shake water over the body without difficulty. The ducks should be allowed to dip their heads under water.

The provision of a good open water system such as troughs improves eye, nostril and feather condition and reduces disease (Knierim et al 2004, Jones et al 2009, Jones and Dawkins 2010a,b, O'Driscoll and Broom 2011, O'Driscoll and Broom 2012). Water troughs must be wide enough and deep enough so that ducks can immerse and wet their head fully. The trough should also be long enough so that there is no competition between ducks for access, although it may not be necessary for all birds to bathe simultaneously (Waitt et al 2009). The Cepso brochure "Le logement collectif pour le gavage des canards' (Cepso 2013) states that there should be at least 800 mm length of water trough per cage, but it is not clear if this is dependent on group size. In addition, the width and depth dimensions of the troughs are not supplied. The brochure shows some of the systems with the troughs located centrally with cage units either side, and some have the troughs on the outside of the cage, on the same side as the force-feeder. Ensuring water cleanliness may be difficult, especially when troughs are on the periphery of the cage, on the same side as the force-feeder. Also, birds may be hesitant to approach this side because of its association with the force-feeder and with being force-fed. If the troughs cannot be kept clean, a separate supply of water for drinking purposes only (such as nipple drinkers) may be necessary (Liste et al 2013, Broom and Fraser 2015).

While studies state that water troughs are provided for drinking and head immersion, to our knowledge none published so far have examined whether the trough is actually used for what it is designed, or reported on water cleanliness and behaviours of force-fed ducks at the troughs. The troughs should be long, wide and deep enough to allow the duck to immerse its head fully in water, but there is little information on the optimal dimensions of water troughs. Dimensions are available for troughs used in experimental conditions in British studies of farmed ducks, for example: 950 mm long, 125 mm wide and 80 mm deep (Jones et al 2009, Waitt et al 2009) or 1600 mm long, 150 mm wide and 100 mm deep (O'Driscoll and Broom 2011). However, ducks in these studies are younger, smaller and lighter than ducks at force-feeding, and the troughs would be placed on the ground rather than being attached to cages. A Belgian scientific report on foie gras production states legislation of 2010 that specifies the provision of troughs that are at least 75 mm deep but only at least 65 mm wide (Federale overheidsdienst 2014). Little attention seems to have been paid to water trough dimensions in other studies, or to whether the birds are able to perform this immersive behaviour in addition to drinking, or to water cleanliness and maintenance of troughs. As ducks lack sweat glands immersion in water, as well as panting, is a vital homeostatic mechanism for thermoregulation. It is of paramount importance to force-fed birds who are subjected to a high level of thermal stress due to the large amounts of food fed.

In the past, force-fed mulard ducks kept in individual cages either had access to water via nipple drinkers (Rodenburg et al 2005) or via troughs but, because of the restrictive cage, the type of trough and increasing bird size, they could not immerse their heads in the water, spread water over their feathers and self-groom. They were unable to keep their eyes, beaks, nostrils and feathers clean and photographs of force-fed ducks often showed them with dirty faces and necks, especially towards the end of the force-feeding period. During force-feeding, which is a messy procedure, the maize mash is likely to contaminate the bird, its cage and surroundings. It remains to be seen whether group housing, with the provision of water facilities in the form of troughs, results in cleaner, healthier birds with improved welfare.

Behaviour

Nervousness and hyper-reactivity

Mulard ducks are most often used for foie gras production, and are recognised as being particularly fearful, nervous and hyper-reactive – the term ‘nervosisme’ is used in French. They show panic and flight responses to the approach of humans and are generally described as being ‘sensitive to the environment’ (Guémené et al 2002, Guémené et al 2006b, Laborde and Voisin 2013). These behaviours become evident at 5 to 7 weeks of age. It seems that the move from individual to group housing has brought the problem of “nervosisme” in ducks to the fore.
French scientists have established a research project called “CaNervosisme” in an attempt to address the undesirable behavioural characteristics of ‘nervosisme’. The project includes a large number of different experiments looking at a range of features such as the birds’ phenotype, genotype, genetic manipulations, rearing conditions, group size, behavioural and physiological responses and exposure to humans (Guémené et al 2002, Guémené et al 2004, Guémené et al 2006b).

Mulard ducks with white plumage are most often used for foie gras production, and are recognised as being particularly fearful, showing panic and flight responses to the approach of humans and generally being highly reactive to their environment. Guémené et al (2002) looked at the effects of genotype (2 strains A and B), phenotype (white, mostly white or coloured plumage) and early controlled exposure to humans on these responses.
Birds were kept in rearing pens until force-feeding 99 days later. Exposure to humans consisted of walking through the group of animals for 5 mins three times a day (5 days out of 7), and of individual handling once daily (5 days out of 7). Individual handling involved collecting the animals at one end of their pen, catching them individually and passing them to the other side of a barrier. The control groups received the minimum amount of human handling necessary to carry out normal husbandry procedures. Three behavioural tests (response to human approach in a corridor, response to a novel object or to a man in an arena, and an open field test) were performed at 2 to 3 weeks and 9 to 10 weeks of age. After the birds were transferred to individual cages for force-feeding, they were examined for their response to the approach of the force-feeder on 4 occasions (after 3rd, 15th, 21st and 25th meal, 2nd, 7th, 10th and 12th day). The birds’ reactions were scored as aggressive, indifferent or fearful.
In general, plumage colour had no effect on behavioural responses, whereas genotype and human handling did. Handling had a positive effect, independent of genotype or phenotype, as birds were less likely to show escape responses to the approach of humans than non-handled birds. However, the results of the ‘response to the force-feeder’ are less obvious; both handling and experimental group factors had a significant effect on the birds’ behaviour on the first test occasion (3rd meal) but not thereafter. Within the handled groups, ducks of the B genotype with coloured plumage were more indifferent, less aggressive and less frightened, whereas in the non-handled group, ducks of the A genotype with white plumage were less indifferent, more aggressive and more frightened. The authors raise the possibility that the impression that ducks of white plumage are more fearful may be due to husbandry factors, because white ducks are more likely to be kept in large flocks in

intensive production systems where contact with humans is minimal. Birds with coloured plumage are more often found in smaller flocks where there is more human contact. The lack of effect of previous handling on the response to the force-feeder, except on the first test, suggests that aversion to the force-feeder or force-feeding process over-rides the positive effect of handling.

Faure et al (2003) compared the susceptibility to fear and stress in two species and their hybrid. Male muscovy and male Pekin ducks and the male hybrid, the mulard, were tested for fear and stress reactions using tonic immobility and fear of humans behavioural tests. Blood was collected for corticosterone assay i) 10 minutes after the tonic immobility test ii) before and after 10 minutes of restraint in a net, a treatment that has been shown to cause a significant increase in plasma corticosterone, and iii) before and after the injection of 5 g/kg of synacthen (ACTH agonist).
The muscovy duck showed lower levels of fear reactions than the Pekin in the majority of behavioural tests (six of eight). Corticosterone levels were also nearly always the lowest in muscovy ducks (five of six tests). In general the muscovy duck appeared to be less fearful and less susceptible to hypothalamus-pituitary-adrenocortical (HPA) responses than the Pekin duck. The mulard was similar to one parent or midway between the two for most tests but showed heterosis (a greater response than the two parents) for fear of humans at 10 weeks of age. Corticosterone levels in the mulard duck were midway between the two parents in most tests. The best indication of the magnitude of the adrenal response is the increase in corticosterone in relation to basal and maximal concentrations, so comparisons of actual increases in concentration across species give limited information.

In a more recent publication, Arnaud et al (2008) examined further the behavioural and physiological fear responses in muscovy, Pekin and mulard ducks. Both parental genotypes were very sensitive to stressors and highly fearful, especially to human presence or handling. However, they showed different behavioural responses: Pekin ducks showed greater locomotor activity and panic behaviour, while muscovy ducks showed greater avoidance. Hybrids showed greater panic responses and fear of humans, and appeared to be more sensitive to social stress (isolation from other ducks) than the two parent types, evidence of heterosis. A significant heterosis effect was also found for basal adrenal activity, with mulard ducks having higher basal levels of corticosterone than parental lines.

It has long been recognised by force-feeders that, in addition to genetics, the provenance of the birds influences whether they are of the ‘calm’ or ‘nervous’ type. Laborde and Voisin (2013) carried out extensive questionnaire and telephone surveys of force-feeders and duck farmers, to explore aspects of husbandry and practice prior to force-feeding that may affect the birds’ behaviours during force-feeding. Producers were divided into two groups, those that produced ‘nervous’ and those that produced ‘calm’ birds. Behavioural group did not affect production statistics such as mortality or liver weight; effects were largely such that force-feeding was more difficult with ‘nervous’ groups. Birds were described as agitated, retreating from the gavage tube, causing wounds to conspecifics and the force-feeder, making the procedure last longer and increasing the mental and physical strain on the force-feeder.
The husbandry and management of the birds prior to their entry into indoor housing, for the final 2-week period of force-feeding, was shown to affect their fearfulness during force-feeding. Different aspects seemed to have positive, negative or no effects although the differences between groups were not marked (P values are close to but

greater than 0.05; statistical methods are not described). Birds subjected to multiple manipulations, for example weighing and vaccination, had a tendency to be less nervous as did birds fed by manual rather than automated methods prior to force-feeding. Birds reared on sandy soils, that experienced a rapid transfer to the force-feeding site, or that came from remotely located farms, were more nervous.

This preliminary study has highlighted some of the many factors that may have an effect on the subsequent behaviours of ducks during force-feeding. 'Nervosisme' seems to have two main components: fear of humans and fear of the environment. These two different kinds of fear are likely to have different aetiologies, paths of development and influences and, therefore, require different remedial approaches.

Reactive, nervous and fearful ducks clearly have poorer welfare than calm ones, because they are less well able to cope with environmental changes and with the presence of humans. This has particularly severe effects on welfare for these birds because the foie gras production process involves sudden environmental changes and close human contact. For example, ducks are moved to the outdoors at the end of the starter period and then suddenly brought indoors to an unfamiliar environment for force-feeding. In addition, caged ducks are subjected to repeated close contact with the force-feeder, who they cannot avoid, and to the forcible introduction of food into the oesophagus, a novel and unpleasant sensation especially at the early stages when the duck's gag reflex still occurs. These experiences are likely to lead to failure of ducks with 'nervosisme' to cope with their environment and with human contact and result in poor welfare.

Other welfare considerations

The human-animal relationship

A widely held view in many communities is that farm animals can suffer, and that animal suffering is the most important consideration in our moral obligations towards animals (Hemsworth 2007). Frequently raised concerns about farm animal welfare include indoor housing, confinement and routine husbandry procedures (Hemsworth 2007, Broom and Fraser 2015); these have been highlighted in this review. Stockmanship, in contrast, receives less attention even though stock people have a major impact on the welfare of their livestock.

There is substantial evidence that negative interactions between humans and animals increase the animals' fear and stress (Hemsworth 2007). In the case of foie gras production, the relationship between the force-feeder and the force-fed ducks has received little attention. Perhaps this is because the force-feeder is often only involved in the final stage rather than in the whole production process, and because their work is normally restricted to force-feeding and cleaning activities. Concerns have been raised that, with the obligatory introduction of group housing in 2016, the work of the force-feeder will take longer and be more difficult. Not surprisingly, Litt (2010) found that force-feeding took longer when birds were group housed than when in the small cages with their heads sticking out. Workers had to modify their technique and movements, and access to birds was more difficult. Due to the difficulties in catching and restraining birds, a containment system of movable front and back walls has been devised, which reduces the birds' ability to struggle, resist or escape. This may make force-feeding quicker and easier, but causes fear and has a negative impact on the stockperson-animal relationship. Fearful animals are more difficult to handle and little or no habituation to force-feeding is likely to occur.

Domestic animals usually develop a relationship with the person looking after them, especially if the person provides food and other positive resources such as bedding, and activities such as talking, petting and grooming. The need for containment of the ducks, to bring them towards the force-feeder and to immobilise them, strongly suggests that the ducks find restraint, the force-feeding procedure, the food being force-fed and the force-feeder, aversive. The responses seen, such as struggling and escape behaviours, are typical of farm animals subjected to routine procedures that they find painful, frightening and unpleasant (Vinuela-Fernandez et al 2011). If ducks were being offered acceptable food and did not find the procedure painful or otherwise aversive and the force-feeder frightening, there would be no need for containment. Instead, they would move forward voluntarily towards the force-feeder and stay still while fed because food is a necessary and desirable resource.

Control over the environment and motivation

The foie gras industry speaks of 'respect for the animal' in the sense of consideration of its welfare, yet there is a clear failure to meet the duck's needs. The duck is forced to ingest food against its will, and is unable to regulate intake in terms of quantity or quality. An important concept in relation to understanding animal welfare is the control which an individual has over its environment (Broom 1991). Welfare is poorer when the individual lacks control, is affected by the consequences of lack of control

i.e. it fails to cope, or feels pain or fear (Broom 2008). This is relevant to foie gras production; the animal lacks control over an aspect of its life that is crucial to its survival, the acquisition and ingestion of appropriate quantities of an appropriate diet.
Force-feeding prevents the duck from performing its normal, species-specific foraging and feeding behaviours, so its motivations to search for and ingest food in order to achieve satiety and homeostasis cannot be fulfilled. Motivated behaviours have two phases: an 'appetitive' phase in which the animals search or prepare for the opportunity to perform a 'consummatory' phase (Mason and Burns 2011). In the case of food, their expression is vital to the animal's survival so both phases are driven by strong motivations, and emotions appear to be important in their control. Being unable to satisfy strong motivations leads to frustration (Mason and Burns 2011). The appetitive (foraging and dabbling) and consummatory (eating) behaviours of force-fed ducks are prevented and this is likely to lead to frustration and poor welfare.

The European Charter and the Welfare Quality® project

In 2008 the European Federation of Foie Gras, consisting of all the representatives of foie gras producing countries in the European Union, was signatory to a European Charter on the "breeding of waterfowl for foie gras" (see http://www.eurofoiegras.com/docs/EUROFOIEGRAS_CHARTE_UK.pdf). (The term 'élevage' is not translated accurately; the Charter is not about breeding but about rearing and fattening, or production).
The Charter is derived from the twelve criteria of the Welfare Quality® project (see below). It is worth noting that the term 'assisted feeding' is used in the English and 'gavage' in the French version of the Charter. The Federation claims that, "if performed by professionals under regulated conditions, gavage does not cause any suffering to the animals" (see http://www.eurofoiegras.com/en/page/euro-foie-gras_p134/). A support programme called 'Palmi G Confiance' was created in 2014 to help foie gras producers meet the standards of the European Charter with regard to animal welfare and good practice.

The four welfare principles and 12 criteria proposed by the Welfare Quality® project (Blokhuis et al 2010) are a development of the Five Freedoms concept (Broom and Fraser 2015). They present general guidelines on the needs of animals and how they may be met. A need is a requirement, which is part of the basic biology of an animal, to obtain a particular resource or respond to a particular environmental or bodily stimulus (Broom 1996, Broom and Fraser 2015).
While the Welfare Quality® assessment system emphasises the use of animal-based measures, it also includes important resource-based and management-based ones. Between 30 and 50 measures are collected and categorised into 12 criteria which are further integrated into 4 welfare principles: good feeding, good housing, good health and appropriate behavior.
The Welfare Quality® assessment system is criticised for taking a long time to perform and being overly complicated (Leterrier et al 2015). Researchers are working with the whole poultry industry to develop a simple method that can be used on a large scale and is largely based on animal measures. Some research is focussed on identifying measures easily taken in the abattoir that are highly correlated with measures on-farm that are more difficult to collect (Litt et al 2015a). While this approach may be premature for ducks kept for foie gras production, due to the imminent changes in housing and the lack of good physiological and behavioural data

from group-housed birds, we have made a preliminary attempt at assessing the welfare of ducks in foie gras production using the Welfare Quality® assessment system (Table 1, next page)). Based on the information available to us, and contrary to the aspirations of the European Charter, only three of the 12 criteria and none of the welfare principles are met in current systems of foie gras production.

Other stages of foie gras production

While the primary aim of this review has been to highlight the welfare problems in the last stage of foie gras production, when ducks are force-fed, welfare problems have also been identified in the first two stages, starter and growth. These include the early, frequent and rapid development of footpad dermatitis, hock burns and breast blisters, fear of humans and high sensitivity to the environment, and lack of access to open water for bathing or at least full immersion of the head. It seems that under commercial conditions water is normally only provided by nipple drinkers, despite ducks being aquatic animals who spend most of their lives close to or on water (RSPCA 2015, Broom and Fraser 2015). The Council of Europe (1999) requirements for ducks state that they should be able to dip their heads in water and spread water over their feathers; this is possible with baths, troughs and showers but not with nipple or bell drinkers. If properly managed, the provision of open water as baths, troughs or showers should not lead to disease. On the contrary, a good open water system can improve eye, nostril and feather condition, and reduce disease (Jones et al 2009; O'Driscoll and Broom 2011, Liste et al 2012).

Table 1. Principles and criteria that underpin the Welfare Quality® assessment system

Welfare principles	**Criterion**	**Is it met?**	**Example of how criterion is or is not met**
Good feeding	Animals should not suffer from prolonged hunger, i.e. they should have a sufficient & appropriate diet.	No	Duck is fed a diet that is neither appropriate nor sufficient; it cannot regulate its intake to achieve satiety & homeostasis
	Animals should not suffer from prolonged thirst, i.e. they should have a sufficient & accessible water supply.	Yes	There may be problems with maintaining cleanliness, ensuring ease of access to water troughs & trough design
Good housing	Animals should have comfort around resting.	No	There is no resting area & no bedding, the floor consists of wire or plastic mesh
	Animals should have thermal comfort, i.e. they should neither be too hot nor too cold.	No	There is thermal stress due to large amounts of high energy food leading to prolonged panting
	Animals should have enough space to be able to move around freely.	Yes	More behavioural research is necessary to confirm optimal cage size & design & stocking density
Good health	Animals should be free of physical injuries.	No	Injuries due to containment, capture, handling & force-feeding occur
	Animals should be free of disease, i.e. farmers should maintain high standards of hygiene & care	No	Footpad & hock dermatitis, lesions to breastbone are frequent & often severe; liver steatosis is caused deliberately
	Animals should not suffer pain induced by inappropriate management, handling, slaughter, or surgical procedures (e.g. castration, dehorning).	No	Containment, capture, handling & force-feeding may be sources of pain; high prevalence of wing lesions caused by handling & transport to abattoir
Appropriate behaviour	Animals should be able to express normal, non-harmful, social behaviours, e.g. grooming.	Yes	Further research needed on social behaviour in group housing, optimal group size & social behaviours, signs of good welfare
	Animals should be able to express other normal behaviours, i.e. it should be possible to express species-specific natural behaviours such as foraging.	No	There is no substratum for foraging; further research is necessary on the use of water troughs, dry & wet preening & grooming behaviours
	Animals should be handled well in all situations, i.e. handlers should promote good human-animal relationships.	No	Catching & handling for force-feeding does not promote good human-animal relationships; poor handling during transport prior to slaughter causes wing lesions
	Negative emotions such as fear, distress, frustration or apathy should be avoided whereas positive emotions such as security or contentment should be promoted	No	Fear, distress, frustration, pain & other negative emotions are very likely when ducks are subjected to the stages of foie gras production, especially at force-feeding. Problem of nervousness & hyper-reactivity in hybrid mulard ducks

Conclusions

From our review of the available scientific literature, we have reached the following animal welfare-related and general conclusions:

Animal welfare-related

1. In 2006 the national average mortality of force-fed birds was 2.4% and in 2013 it was 2.2%. The Institut Technique de l'Aviculture reports mortality of 2 to 5%. These data compare unfavourably with mortality rates of muscovy ducks in fattening units in the UK, where in the two weeks before slaughter the mortality rate was 0.2%.

2. Birds in foie gras production are the only farmed animals that are not allowed to use their basic biological mechanisms to regulate their own food intake.

3. Ducks are motivated to perform normal foraging activities, such as searching for food, pecking, nibbling, dabbling, up-ending and swallowing. Their need to forage is not met during force-feeding.

4. Since force-feeding prevents the duck from performing its species-specific foraging and feeding behaviours, its motivations to search for and ingest food cannot be fulfilled and, as in many other species, this is likely to lead to frustration.

5. Ducks are fed such large amounts of food that they are unable to maintain satiety and homeostasis. They are denied the opportunity to show normal feeding behaviour in accordance with their appetite.

6. With force-feeding the duck lacks control over an aspect of its life that is crucial to its survival, the ingestion of appropriate quantities of an appropriate diet. Loss of control leads to very poor welfare.

7. Force-feeding causes the birds to become obese, leading to foot and leg disorders that reduce their ability to move and are likely to be painful.

8. Force-feeding may cause injury and pain to the bill, face, eyes, nostrils, neck and upper digestive tract. However, descriptive studies of these conditions are lacking.

9. Bone fractures and other wing lesions are common and are most likely to occur at the stages of collection, transport to the abattoir and shackling.

10. Ducks are force-fed large amounts of an unbalanced diet that does not meet their nutritional needs and leads to significant liver, bone and other pathology.

11. Force-feeding causes a degree of liver pathology, especially steatosis (fatty liver), that is desirable and of value to producers of foie gras but greatly increases the duck's risk of premature death.

12. There is clear evidence of liver pathology: a reduction in the liver's ability to detoxify, (slower BSP clearance, longer BSP half-life) and liver cell damage (raised liver enzymes) at the end of the force-feeding period. The reversibility of steatosis does not mean that the changes in the liver are not pathological.

13. Force-feeding a nutrient-deficient diet in large amounts leads to gross hepatomegaly (liver enlargement), which can cause pain and difficulties in balancing and movement.

14. The enlarged liver may compress respiratory airsacs and other abdominal organs, and where liver function is severely compromised hepatic encephalopathy (effects of toxins on the brain) may ensue.

15. Due to the large amount of high-energy food, ducks are placed under considerable thermal stress. They spend a large proportion of their time panting in order to thermoregulate and maintain physiological homeostasis.

16. Levels of blood corticosterone are a poor indicator of welfare if measured in association with feeding in mulard ducks. They must be considered in conjunction with other welfare indicators such as health, pathology, other physiological measures, behaviour and other indicators of mental state.

17. Individual cages greatly restrict the bird's movements and do not allow it to show more than a minimal behavioural repertoire, with consequent very poor welfare.

18. Ducks are gregarious and require cages big enough so that they are able to fully stretch their wings, preen and groom, walk and show normal social interactions and other behaviours. Group cages are small, usually offering a surface area per bird of only 1200-1300 cm^2.

19. Group cages are barren, containing only conspecifics and water troughs. It is not clear whether the water troughs currently used allow full immersion of the duck's head and the normal bathing that is essential for preening.

20. Council of Europe recommendations and the European Federation of Foie Gras Charter guidelines state that ducks should be able to express species-specific behaviours. However, group-housed ducks are not provided with substratum for foraging.

21. Council of Europe recommendations and the European Federation of Foie Gras Charter guidelines state that ducks in group cages should be able to rest in comfort. However, ducks are usually housed on mesh floors without bedding.

22. The group cage has a steel or plastic mesh floor that may worsen contact dermatitis (foot, toe, hock and breast lesions).

23. Due to the difficulties in catching and restraining birds for force-feeding, a containment system has been devised which reduces the birds' ability to struggle, resist or escape. This makes force-feeding quicker and easier, but causes fear and has a negative impact on the stockperson-animal relationship.

24. Group-housed birds may be more susceptible to injury from poor force-feeding technique, handling, getting caught in the cage's containment mechanism, or restrained in a bad position for a long time.

25. The condition of ducks deteriorates as they pass through the successive stages of foie gras production. Painful skin lesions such as contact dermatitis are frequent and develop early in the production process. They are often severe by the force-feeding stage, and other body injuries also occur.

26. Ducks in the first two stages of foie gras production, starter and growth (rearer), may not have access to open water for bathing, or at least for full immersion of the head, despite having a need for open water to maintain plumage and body condition and to thermoregulate.

27. Compared with controls, force-fed ducks show a variety of behavioural changes which indicate poor welfare such as lack of mobility, increased time lying down, reduced grooming and preening and social interactions, and prolonged panting.

28. The oropharynx in birds is adapted to perform the gag reflex to prevent material from entering the throat except as part of normal swallowing, and protects against choking and aspiration. Initially, force-feeding stimulates this reflex but after a certain time it stops. The adaptation time required for the gag reflex to be extinguished, and how the duck is affected by this, are not known.

29. Ducks are fed by having a tube forcibly inserted into their oesophagus twice daily for up to 15 days. They are reluctant to enter a pen where they are force-fed, an indication that they find force-feeding aversive. There is no convincing evidence that ducks show a lesser avoidance response to the force-feeder than to another (unfamiliar) person.

30. Other duck welfare problems include fear of humans and a high degree of nervousness and reactivity to the environment. Reactive, nervous and fearful ducks are less well able to cope, with consequent poor welfare.

31. With current methods of foie gras production, only three out of 12 criteria and none of the welfare principles described in the Welfare Quality® project are met.

General

1. In the last 10 years in France, national production of foie gras has increased by 11%, from 17,217 tonnes in 2003 to 19,067 tonnes in 2013 with 98% coming from ducks. Profit margins have decreased as costs have increased.

2. Migratory birds have mechanisms for storing food before migration. The greylag goose *Anser anser,* traditionally the main species used for foie gras production, is migratory. The muscovy and the mulard duck are non-migratory and most populations of wild mallard migrate little. Pre-migration food storage may lead to liver size increase but probably not more than a doubling of size.

3. By the end of the force-feeding period, the duck's liver is 7 to 10 times the size of a normal liver with an average weight of 550 to 700 g and a fat content of 56%. This increase in liver weight is accompanied by a live-weight gain in the range of 50 to 85%.

4. Fatty liver results from an increased capacity of hepatic lipogenesis, an insufficient hepatic capacity to export newly synthesised triglycerides, and a limited capacity of peripheral tissues to take up circulating lipids, thus favouring their return towards the liver.

5. Spontaneous over-eating in geese can be stimulated by manipulating day length and feeding regimes, usually restriction followed by *ad-libitum* feeding, and may eventually become a method of foie gras production that does not require force-feeding.

6. Due to the difficulties in catching and restraining group-housed birds for force-feeding, a containment system has been devised which reduces the birds' ability to struggle, resist or escape. It consists of a movable back wall which pushes the birds towards the front, and a front vertical wall which descends over them and prevents them from escaping or moving much ('peigne de contention').

7. Compared with individual housing, group housing leads to a decrease in liver weight, an increase in the weight of the 'magret', an increase in the time taken to perform the force-feeding and an increase in the amount of water used in cleaning. At slaughter, there are more liver defects and fewer haematomas but more scratches on the duck's carcass.

8. The consumption of foie gras may have negative effects on humans. Duck or goose-derived foie gras contains amyloid protein which could hasten the development of amyloidosis in a susceptible population.

References

Arnaud I, Mignon-Grasteau S, Larzul C, Guy G, Faure JM, Guémené D (2008) Behavioural and physiological fear responses in ducks: genetic cross effects. *Animal* 2 (10): 1518-1525

Arroyo J, Fortun-Lamothe L, Dubois J-P, Lavigne and Auvergne A (2012) Conduite et gestion des transitions alimentaires chez les oies destinées à la production de foie gras. *INRA Prod. Anim.,* 25: 419-430

American Veterinary Medical Association (AVMA) (2014) Welfare implications of foie gras production. American Veterinary Medical Association Animal Welfare Division, Illinois, USA, 1-4

Babilé R, Auvergne A, Andrade V, Héraut F, Bénard G, Bouiller-Oudot M and Manse H (1996) Réversibilité de la stéatose hépatique chez le canard mulard. *2èmes Journées de la Recherche sur les Palmipèdes à Foie Gras*, Bordeaux, 12-13 Mars: 107-110

Baèza E, Marie-Etancelin C, Davail S and Diot C (2013) La stéatose hépatique chez les palmipèdes. In : Palmipèdes à foie gras. Fortun-Lamothe L. (Ed). Dossier, *INRA Prod. Anim* 26: 403-414

Bassett A (2009) Animal Welfare Approved Technical Advice Fact Sheet No. 7 Foot Pad Dermatitis in Poultry. See: www.animalwelfareapproved.org Accessed July 3 2015

Bénard G, Bénard P, Prehn D, Jouglar JY and Durand S (1998) Démonstration de la réversibilité de la stéatose hépatique obtenue par gavage de canards mulards. Étude réalisée sur 3 cycles de gavage. *3èmes Journées de la Recherche sur les Palmipèdes à Foie Gras*, Bordeaux. 27-28 Octobre: 49-52

Bénard G, Bengone-Ndong T, Prehn D, Durand S, Labie C and Bénard P (2006) Contribution à l'étude de la physiologie du canard en gavage: étude de la stéatose hépatique. *Bull Acad Vét France* 159 (1): 43-51

Bijja M, Dubois JP, Lavigne F, Auvergne A, Arroyo J and Fernandez X (2013) Influence de l'ombre et du soleil sur le comportement et le bien-être des canards mulards pret à gaver en periode estivale. *10èmes Journées de la Recherche Avicole et Palmipèdes à Foie Gras.* La Rochelle: 238-242

Blokhuis HJ, Veissier I, Miele M and Jones B (2010) The Welfare Quality® project and beyond: Safeguarding farm animal well-being. *Acta Agriculturae Scandinavica, Section A — Animal Science* 60: 129-140

Bonnefont C, De Leotoing d'Anjony H, Guy G, Laverze J-B, Brachet M, Fortun-Lamothe L and Fernandez X (2015) Effet de la stimulation lumineuse sur le déclenchement de la stéatose hépatique chez l'oie en absence de gavage. (Effect of light programs on the spontaneous fattening of goose liver without over-feeding). In:

11èmes Journées de la Recherche Avicole et des Palmipèdes à Foie Gras pp 1077-1081 Presented at 11 Journées de la Recherche Avicole et des Palmipèdes à Foie Gras, Tours, FRA (2015-03-25 - 2015-03-26). FRA : INRA- ITAV Accessed July 3 2015
http://prodinra.inra.fr/record/294980

Broom DM (1991) Assessing welfare and suffering. *Behavioural Processes* 25: 117-123

Broom DM (1996) Scientific research on veal calf welfare. In: Veal Perspectives to the Year 2000. Proceedings of International Symposium, Le Mans, France. Fédération de la Vitellerie Francaise, Paris, pp. 147–153.

Broom DM (2008) Welfare Assessment and Relevant Ethical Decisions: Key Concepts. *Annu Rev Biomed Sci.* 10: T79-T90

Broom DM and Fraser AF (2015) Chapter 4 Motivation. In: Domestic Animal Behaviour and Welfare, 5th edition. Wallingford UK: CABI pp 46-60

Broom DM and Johnson KG (2000) Stress and Animal Welfare. Dordrecht: Kluwer.

Carrière ML, Hermal J-M, Bernadet M-D, and Servière J (2006a) Modification d'expression de la protéine PPARγ au cours de la stéatose hépatique induite par gavage chez le canard mulard: implication dans les processus inflammatoires? *7èmes Journées de la Recherche sur les Palmipèdes à Foie Gras,* Arcachon, 18 et 19 octobre*:* 79-83

Carrière ML, Roussel S, Bernadet M-D, Duvant-Ponter C and Servière J (2006b) Effet du gavage sur le comportement post prandial des canards mulards. *7èmes Journées de la Recherche sur les Palmipèdes à Foie Gras,* Arcachon, 18 et 19 octobre: 84-89

Cepso (2013) Le logement collectif pour le gavage des canards. See:
http://www.cepso.chambagri.fr/fileadmin/documents_cepso/fichiers_PDF/logements_gavage/BROCHURE_CEPSO_2013_VF_01.pdf
Accessed 3 July 2015

Chen KL and Chiout PW (2001) Oral treatment of mule ducks with Arsenicals for inducing fatty liver. *Poultry Science* 80 (3): 295-301 See:
http://www.ncbi.nlm.nih.gov/pubmed/11261559
Accessed 3 July 2015

Council of Europe (1999) Recommendation concerning Muscovy ducks (Cairina moschata) and hybrids of Muscovy and domestic ducks (*Ana platyrhynchos*) See:
http://www.coe.int/t/e/legal_affairs/legal_co-operation/biological_safety_and_use_of_animals/farming/Rec%20Muscovy%20ducks%20E%201999.asp
Accessed 3 July 2015

Food and Agriculture Organization of the United Nations (FAO) (2002) Chapter 11. Fatty liver or foie gras production. In Food and Agriculture Organization of the

United Nations Animal Production and Health Paper – 154. Editors Buckland R and Guy G (ISSN 0254-6019). See: www.fao.org/DOCREP/005/Y4359E/Y4359E00.HTM
Accessed 3 July 2015

Faure JM, Guémené D, *Destombes N,* Gouraud P and Guy G (1998) Test d'aversion au gavage et au gaveur chez le canard mulard mâle. *3èmes Journées de la Recherche sur les Palmipèdes à Foie Gras*, Bordeaux, 27-28 Octobre: 75-78.

Faure JM, Guémené D and Guy G (2001) Is there avoidance of the force feeding procedure in ducks and geese? *Animal Research* 50: 157-164

Faure JM, Val-Laillet D, Guy G, Bernadet MD and Guémené D (2003) Fear and stress reactions in two species of duck and their hybrid. *Hormones and Behaviour*. 43 (5): 568-72

Federale overheidsdienst (2014) Production de foie gras: Rapport scientifique réalisé à la demande du Conseil du Bien-Être des Animaux de Belgique. See: http://www.health.fgov.be
Accessed 3 July 2015

Fernandez X, Guy G and Lamothe L (2013) Induction d'une stéatose hépatique spontanée chez l'oie grise (*Anser anser*) - Rôle de l'hyperphagie provoquée. Presented at 5. Journées d'Animation Scientifique du département Phase (JAS Phase 2013), Paris, FRA (2013-10-03 - 2013-10-04). See:
http://prodinra.inra.fr/record/279396
Accessed 3 July 2015

Fernandez X, Gérard G, Laverze J-B, Fortun-Lamothe L and Lazzarotto V (2015) Analyse compare de la composition chimique et des qualités sensorielles des fois d'oies issus du gavage ou d'un engraissement spontané *11èmes Journées de la Recherche Avicole et des Palmipèdes à Foie Gras,* Tours, 1181-1185

Flament A, Delleur V, Poulipoulis A and Marlier D (2012) Corticosterone, cortisol, triglycerides, aspartate aminotransferase and uric acid plasma concentrations during foie gras production in male mule ducks (*Anas platyrhynchos* × *Cairina moschata*) *British Poultry Science* 53 (4): 408-413. doi: 10.1080/00071668.2012.711468.

Gabarrou JF, Salichon MR, Guy G, and Blum JC (1996) Hybrid ducks overfed with boiled corn develop an acute hepatic steatosis with decreased choline and polyunsaturated fatty acid level in phospholipids. *Reproduction Nutrition Development, EDP Sciences*. 36(5): 473-484.

Greene JA, McCracken RM and Evans RT (1985) A contact dermatitis of broilers—Clinical and pathological findings. *Avian Pathology* 14: 23–38

Greger M. (2008) Amyloid fibrils: potential food safety implications *Int. J. Food Safety, Nutrition and Public Health* 1 (2): 103–115.

Guémené D, Guy G, Noirault J, Garreau-Mills M, Gouraud P, Faure JM (2001) Force-feeding procedure and physiological indicators of stress in male mule ducks. *British Poultry Science* 42(5): 650-657.

Guéméné D, Faure JM, Gobin E, Garreau-Mills M, Doussan I, Gouraud P and Guy G (2002) Effets de la familiarization à l'homme sur les réponses comportementales de peur chez le canard mulard. *5èmes Journées de la Recherche sur les Palmipèdes à Foie Gras,* Pau, 9 et 10 octobre: 58-62

Guémené D, Larzul C, Bouy S, Bernadet MD, Guy G and Faure JM (2004) Couleur du plumage et déterminisme des comportements de peur chez le canard mulard. *6èmes Journées de la Recherche sur les Palmipèdes à Foie Gras*; Arcachon (FRA); 99-104

Guémené D and Guy G (2004) The past, present and future of force-feeding and "foie gras" production. *World's Poultry Science Journal* 60 (2): 210-222

Guémené D, Guy G, Noirault J, Destombes N and Faure JM (2006a) Rearing conditions during the force-feeding period in male mule ducks and their impact upon stress and welfare. *Animal Research* 55 (5): 443-458

Guémené D, Bernadet M-D, Richard-Mialon M M, Val-Laillet D, Bouy S, Arnaud I, Gobin E, Gardin E, Couty M, Garreau-Mills M, Gouraud P, Meyer I, Larzul C, Grasteau S, Dubos F, Coudurier B, Faure JM and Guy G (2006b) Le "nervosisme" chez le canard mulard. Synthèse des acquis de la recherche et perspectives. In: *7èmes Journées de la Recherche sur les Palmipèdes à Foie Gras* (p. 66-73).
Presented at 7. Journées de la Recherche sur les Palmipèdes à Foie Gras, Arcachon, FRA (2006-10-18 - 2006-10-19). Paris, FRA: ITAVI. http://prodinra.inra.fr/record/12271

Guémené D, Guy G, Mirabito L, Servière J and Faure JM (2007) Waterfowl welfare and rearing conditions for meat and foie gras production (Bien-être et élevage des palmipèdes) *Productions Animales* 20 (1): 53-58

Guérin JL (2015) L'élevage du canard mulard destine au gavage. Ecole Nationale Vétérinaire Toulouse, See: http://www.avicampus.fr/PDF/PDFzoot/mulard.pdf
Accessed July 3 2015

Guy G, Guémené D and Servière J (2007) Le canard autogavant et/ou le foie gras sans gavage : mythe ou réalité réflexions sur les perspectives de recherches et d'applications. In: *Réunion du Groupe Palmipèdes INRA* (p. 13-14). Presented at Réunion du Groupe Palmipèdes INRA, Toulouse, FRA (2007-03-06). Paris, FRA: INRA Editions. See: http://prodinra.inra.fr/record/14032
Accessed July 3 2015

Guy G, Fortun-Lamothe L, Bénard G and Fernandez X (2013) Natural induction of spontaneous liver steatosis in Greylag Landaise geese. *Journal of Animal Science* 91 (1): 455-464

Harr KE (2005) *Chapter 23 Diagnostic Value of Biochemistry*. In Clinical Avian Medicine volume 2. Editors Harrison GJ and Lightfoot T. pp 611-629 See:

http://avianmedicine.net/content/uploads/2013/08/23_biochemistry.pdf
Accessed July 3 2015

Haslam SM, Knowles TJ, Brown SN, Wilkins LJ, Kestin SC, Warriss PD and Nicol CJ (2007) Factors affecting the prevalence of foot pad dermatitis, hock burn and breast burn in broiler chicken. *British Poultry Science* 48 (3) 264-275. doi: 10.1080/00071660701371341

Hemsworth P (2007) Ethical stockmanship. *Australian Veterinary Journal* 85: 194–200. doi: 10.1111/j.1751-0813.2007.00112.x

Hepworth PJ, Nefedov AV, Muchnik IB and Morgan KL (2011) Hock burn: an indicator of broiler flock health. *Veterinary Record* 168: 303-305

Jones TA, Waitt CD and Dawkins MS (2009) Water off a duck's back: Showers and troughs match ponds for improving duck welfare. *Applied Animal Behaviour Science* 116 (1): 52-57

Jones TA and Dawkins MS (2010a) Environment and management factors affecting Pekin duck production and welfare on commercial farms in the UK. *British Poultry Science* 51: 12-21

Jones TA and Dawkins MS (2010b) Effect of environment on Pekin duck behaviour and its correlation with body condition on commercial farms in the UK. *British Poultry Science* 51: 319-325

Knierim U, Bulheller MA, Kuhnt A, Briese A and Hartung J (2004) Wasserangebot für Enten bei Stallhaltung ein Überblick aufgrund der Literatur und eigener Erfahrung. *Deutsche Tierärztliche Wochenschrift* 111: 115-118

Laborde M and Voisin M (2013) Identification des pratiques d'élevage et évaluation de l'impact sur le comportement des canards en gavage. *10èmes Journées de la Recherche Avicole et Palmipèdes à Foie Gras.* La Rochelle: 232-237

Laborde M, Peillod C, Litt J, Bernadet M-D, Guy G, Dubois JP, Arroyo J, Auvergue A, Fortun-Lamothe L and Fernandez X (2010) Bilan des innovations techniques visant à assurer la durabilité de la filiere palmipèdes à fois gras (2007-2009) *9èmes Journées de la Recherche sur les Palmipèdes à Foie Gras*: 217-225

Leterrier C, Guilloteau L, Lensink J and Guesdon V (2015) Actualités des recherches sur le bien-être animal en aviculture issues du Congres International 2014 sur l'évaluation du bien-être des animaux à l'échelle de la ferme. *11èmes Journées de la Recherche Avicole et Palmipèdes à Foie Gras,* Tours, 25-26 Mars: 856-860

Liste G, Kirkden RD and Broom DM (2012) A commercial trial evaluating three open water sources for farmed ducks: effects on health and production. *British Poultry Science* 53: 576—584

Liste G, Kirkden RD and Broom DM (2013) A commercial trial evaluating three open water sources for farmed ducks: effects on water usage and water quality. *British Poultry Science* 54 (1): 24-32. doi: 10.1080/00071668.2013.763900

Litt J (2010) Comparaison de differents modes de lodgements en gavage: influence sur le produit, le bien-être animal et les conditions de travail *9èmes Journées de la Recherche sur les Palmipèdes à Foie Gras*: 203-206

Litt J, Chaumier J, Laborde M, Bernadet M-D, Vogelaer J, Boucher M, and Bignon L (2015a) Mise au point d'une grille d'indicateurs permettant l'évaluation de l'integrité physique du canard mulard. *11èmes Journées de la Recherche Avicole et Palmipèdes à Foie Gras,* Tours, 25-26 Mars: 1012-1017

Litt J, Chaumier J, Bernadet M-D, Laborde M, Vogelaer J, Albaric O, Huguet J-M and Guérin J-L (2015b) Validation histologique du systeme de notation des dermatitis du coussinet plantaire chez le canard mulard à differents ages. *11èmes Journées de la Recherche Avicole et Palmipèdes à Foie Gras,* Tours, 25-26 Mars: 247-251

Litt J, Chaumier J, Laborde M, Bernadet M-D, Vogelaer J, Boucher M, and Bignon L (2015c) Evaluation de l'integrité physique du canard mulard dans des élevages commerciaux: état des lieux. *11èmes Journées de la Recherche Avicole et Palmipèdes à Foie Gras,* Tours, 25-26 Mars: 876-880

Litt J and Pé M-P (2015) Principales évolutions du marché du foie gras et des résultats techniques à l'echelle des ateliers d'élevage et de gavage ces dix dernières années. *11èmes Journées de la Recherche Avicole et Palmipèdes à Foie Gras,* Tours, 25-26 Mars: 147-152

Marlier D and Bauwens V (2012) Rapport final d'activité - Intitulé du projet subventionné : « Aide vétérinaire et technique à la mise en place des cages collectives pour le gavage des palmipèdes, en réponse aux nouvelles normes de bien-être imposées par la Communauté européenne, p 8

Mason GJ and Burn CC (2011) Chapter 7 Behavioural Restriction. In: Animal Welfare 2nd edition. Editors Appleby MC, Mench JA, Olsson IAS and Hughes BO. CABI Wallingford UK, pp 98-119

Mathiaud A, Héraut F, Klein S and Brevault N (2013) Study of a nutritional solution to improve performances and technological yield of "foies gras". *10èmes Journées de la Recherche sur les Palmipèdes à Foie Gras,* La Rochelle: 365-367

Mirabito L, Sazy E, Héraut F, Guémméné D, Faure JM and Guy G (2002a) Effet de la taille du groupe et de la surface allouée pendant la période de gavage chez le canard mulard: I Résultats zootechniques. *5èmes Journées de la Recherche sur les Palmipèdes à Foie Gras*, Pau, 9 et 10 octobre: 76-79

Mirabito L, Sazy E, Héraut F, Faure JM, Guémméné D and Guy G (2002b) Effet de la taille du groupe et de la surface allouée pendant la périodes de gavage chez le canard mulard: II Résultats comportementaux. *5èmes Journées de la Recherche sur les Palmipèdes à Foie Gras,* Pau, 9 et 10 octobre: 80-83

Mirabito L, Guémméné D, Doussan I, Guy G, Héraut F, Sazy E and Faure JM (2002c) Effet de la taille du groupe et de la surface allouée pendant la périodes de gavage chez le canard mulard: III Corticostéronémie. *5èmes Journées de la Recherche sur les Palmipèdes à Foie Gras,* Pau, 9 et 10 octobre: 84-87

Mirabito L, Héraut F, Blériot G, Ducamp C and Sazy E (2006) Logement collectif du canard mulard durant la phase de gavage: les nouveaux systèmes au banc d'éssai. *7èmes Journées de la Recherche sur les Palmipèdes à Foie Gras,* Arcachon, 18 et 19 octobre: 209-213

Mohammed AAA, Abdel-Rahman MAM and Darwish MHA (2014) Force-feeding as a Stress Factor on Muscovy Ducks. *Journal of Advanced Veterinary Research* 4 (4): 166-173

O'Driscoll KKM and Broom DM (2011) Does access to open water affect the health of Pekin ducks (*Anas platyrhynchos*). *Poultry Science* 90: 299–307

O'Driscoll KKM and Broom DM (2012) Does access to open water affect the behaviour of Pekin ducks (*Anas platyrhynchos*). *Applied Animal Behaviour Science* 136: 156– 165

Robin N and Castaing J (2002) Apports alimentaires pour un gavage de canards mulards en moins de 10 jours. *5èmes Journées de la Recherche sur les Palmipèdes à Foie Gras,* Pau, 9 et 10 octobre: 88-91.

Rodenburg TB, Bracke MBM, Berk J, Cooper J, Faure JM, Guémené D, Guy G, Harlander A, Jones T, Knierim U, Kuhnt K, Pingel H, Reiter K, Servière J and Ruis MAW (2005) Review: Welfare of ducks in European duck husbandry systems. *World's Poultry Science Journal* 61: 633-646

Royal Society for the Prevention of Cruelty to Animals (RSPCA) (2015) Watertight: The case for providing farmed ducks with full body access to water. RSPCA, Horsham, West Sussex. See: http://science.rspca.org.uk/sciencegroup/farmanimals/reportsandresources Accessed 3 July 2015

Scientific Committee on Animal Health and Animal Welfare (SCAHAW) (1998) Welfare aspects of the production of foie gras in ducks and geese. CEC, DGXXIV Adopted December 16, 1998. Available at: http://ec.europa.eu/food/fs/sc/scah/out17_en.pdf. Accessed July 3 2015.

Servière J, Bernadet MD, Guy G and Guéméné D (2002) Données neurophysiologiques sur la nociception potentiellement associée à l'ingestion forcée chez le canard mulard. *5èmes Journées de la Recherche sur les Palmipèdes à Foie Gras,* Pau, 9- 10 octobre: 70-75

Servière J, Carrière M, Duvaux-Ponter C, Guy G and Roussel S (2011) Neurogenic inflammation in the upper digestive tract of the mule duck: effect of a chemical algogen and force-feeding. *British Poultry Science* 52 (6): 792-799

Shepherd EM and Fairchild BD (2010) Footpad dermatitis in poultry. *Poultry Science* 89: 2043-2053

Skippon W (2013) The animal health and welfare consequences of foie gras production. *Canadian Veterinary Journal* 54 (4): 403-404

Solomon A, Richey T, Murphy CL, Weiss DT, Wall JS, Westermark GT and Westermark P (2007) Amyloidogenic potential of foie gras. *Proceedings of the National Academy of Sciences of the United States* 104 (26): 10998-11001

Varfolomeev EE and Ashkenazi A (2004) Tumor Necrosis Factor: An Apoptosis Junkie? *Cell* 116: 491-497

Vinuela-Fernandez I, Weary DM and Flecknell P (2011) Chapter 5 Pain. In: Animal Welfare 2nd edition. Editors Appleby MC, Mench JA, Olsson IAS and Hughes BO. CABI Wallingford UK, pp 64-77

Waitt C, Jones T and Dawkins MS (2009) Behaviour, synchrony and welfare of Pekin ducks in relation to water use. *Applied Animal Behaviour Science* 121: 184–189