frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 22 June 2023
DOI 10.3389/fsufs.2023.1098295

OPEN ACCESS

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RECEIVED 14 November 2022
ACCEPTED 19 May 2023
PUBLISHED 22 June 2023

CITATION
Coeugnet P, Labatut J, Duval J and Vourc'h G (2023) Including citizens through co-design in a participatory research project to explore innovative agro-food systems: the case of future dairy livestock systems.
Front. Sustain. Food Syst. 7:1098295.
doi: 10.3389/fsufs.2023.1098295

Including citizens through co-design in a participatory research project to explore innovative agro-food systems: the case of future dairy livestock systems

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Introduction: Livestock farming and its negative impacts are increasingly criticized by society; its evolution toward more sustainable systems is therefore a key aspect of the transition of agro-food systems. It is necessary to rethink livestock systems' research and innovation processes and develop innovative solutions. Including citizens, non-professionals of the sector, who are less influenced by the current organization of the agricultural sector could be an opportunity to generate innovative solutions, but they have been kept away from research and innovation processes so far.

Methods: In this context, we implemented a co-design process involving researchers, livestock professionals, and citizens in a participatory research project aiming at producing knowledge and developing innovative solutions for the future mountain dairy systems. For this, we have adapted the KCP design method known to promote the exploration of innovative solutions, support the agro-ecological transition, and build a common horizon.

Results: The analysis of this collective dynamic and its outputs allowed us to highlight the positive contribution of citizens during the design process, even if they are not livestock experts. The citizens participated in the formulation of new knowledge by questioning the researchers and livestock professionals and were less influenced by the current system. This contributed to the exploration of original and varied solutions for livestock farming systems.

Discussion: This experimentation offers perspectives for including citizens in agro-food systems research and innovation process. It also opens up interesting perspectives for the fields of citizen science and co-design research.

KEYWORDS

innovative design, citizen participation, idea exploration, dairy farming, citizen sciences

1. Introduction

The intensification of livestock farming in the last century has strongly contributed to the many negative impacts of agriculture on the environment (greenhouse gas emissions, soil degradation, water pollution, and loss of biodiversity) (Steinfeld et al., 2006) and on animal and human health (zoonotic epidemics, antibiotic resistance, consumption of animal products associated with an increased risk of cancer) (EFSA, 2006; Groot and van't Hooft, 2016; Diallo et al., 2018; Morand, 2020). The evolution of livestock farming toward sustainable systems respectful of humans, animals, and the ecological state of the planet is a key aspect of agro-food system transitions (Silbergeld, 2019; Garcia et al., 2020). In this context, existing solutions are no longer sufficient, and it is necessary to develop new solutions and research and innovation approaches (Meynard and Dourmad, 2014). While in recent years research and innovation in the agricultural sector have been organized in a top-down manner and have been externalized from farms (Prost et al., 2017), many studies have highlighted the need for the development of research and innovation approaches opened to the participation of a diversity of actors (researchers, professionals, government, and civil society) in a context of global transition (Hirsch Hadorn et al., 2006; Groot Koerkamp and Bos, 2008; Meynard and Dourmad, 2014).

Citizen sciences are forms of scientific knowledge production in which non-academic actors are involved (Haklay et al., 2021). It has developed in different fields and more particularly in the field of sustainable development (Houllier et al., 2017). There is a wide variety of citizen sciences in the literature and there are no commonly accepted terms to characterize. However, the two most common forms are (i) crowd sciences or crowdsourcing, where non-academic actors are responsible for collecting data and do not participate in the formulation of research issues (Haklay, 2013; Franzoni and Sauermann, 2014) and (ii) participatory research or participatory science, where non-academic actors collaborate with researchers in order to define a shared problem (Haklay, 2013; Blangy et al., 2018; Joly, 2020). The main benefits attributed to citizen sciences are (i) the production of knowledge that could not be achieved otherwise (Devictor et al., 2012; Jankowski and Le Marec, 2014; Chandler et al., 2017), (ii) a more socially relevant science through better understanding of field problems by researchers (Johnson et al., 2004; Cornwall, 2008; Waddington et al., 2014), and (iii) a development of participants "skills" (Sumberg et al., 2003; Brossard et al., 2005; Luneau et al., 2021). However, citizen sciences have shown little interest in the inclusion of non-academic actors in order to explore innovative ideas, even though exploration is essential in a context where existing solutions are no longer sufficient and new ones need to be generated (DeHaan, 2011).

For many years, researchers in cognitive psychology interested in creativity have been describing and studying the types of barriers that can impede the generation of ideas (Ward et al., 2004; Abraham and Windmann, 2007). Indeed, people tend to propose solutions based on the most common and accessible knowledge in a specific field. This phenomenon is called "fixation effects" and is defined as unconscious cognitive biases that govern our relationship to the real world and limit our creative capacity (Agogué et al., 2014). These effects can also be reinforced by the group effect (Diehl and Strpebe, 1987). However, several studies point out that a group with a heterogeneity of actors can lead to the design of original and varied ideas provided that methods are mobilized to overcome the fixation effects (Vourc'h et al., 2018). Among them, the KCP (Knowledge-Concept-Proposal) method, based on the organization of design workshops, aims to control these fixation effects (Le Masson et al., 2009). This method is used in organizations of all sizes and sectors to explore solutions that break with the existing method for its dual ability to support the exploration of disruptive solutions (Elmquist and Segrestin, 2009).

Co-design is an approach that involves the end user in a product or service development and design process. It is therefore a user-centered design method where the emphasis is on the active role of users. It has been studied in various research communities from software engineering to management sciences. Different methods can be used such as brainstorming (Wilson, 2013), design thinking (Weller, 2019), scenarios (Turner et al., 2013), or KCP (Le Masson et al., 2009). In fact, there is increasing evidence that co-design better addresses user needs or creates more innovative concepts and ideas (Steen et al., 2011; Mitchell et al., 2016; Trischler et al., 2018). Moreover, while these approaches were not conceived initially for territorial development projects, studies have shown that co-design approaches bringing together different types of actors driven by a common interest allowed the emergence of sustainable communities of innovation, bringing together different actors (inhabitants, experts, elected representatives) (Laousse and Hooge, 2018).

In the agricultural sector, citizen sciences have been used for 40 years (van de Gevel et al., 2020) and, more recently, specific methods of co-design have been developed to explore ways of innovation by involving heterogeneous actors in agricultural and food systems. These studies include a variety of topics, scales, and design methods (Speelman et al., 2014; Dolinska, 2017; Elzen and Bos, 2019; Berthet et al., 2020; Romera et al., 2020). The KCP method in particular has been used in many cases to design the agro-food systems sector and is recognized for promoting agro-ecological transitions (Berthet et al., 2016) and building a common horizon with farmers, technicians, and researchers (Labatut and Hooge, 2016). However, in these approaches, citizens who are not working in relation to the agricultural sector are not included in this type of process, further widening the gap between agriculture and society formed during the last century (Hervieu and Purseigle, 2013). In some cases, citizens were consulted during certain design processes, for example during a co-design process to design future chicken farms (Groot Koerkamp and Bos, 2008), but they were not invited to the exploration of innovative solutions. Yet with little direct connection to agriculture, they are certainly less influenced by the material norms and beliefs of post-modernization and could be less fixed by the current functioning of agro-food systems in contrast to agricultural professionals (Bos et al., 2009) and could therefore propose more original concepts. Nevertheless, while much work has already shown the interest of mobilizing users in co-design processes, in our case, citizens are not the direct users of the innovations produced. They are indirect users because they consume the products from these agro-food systems, and so can be positively or negatively impacted by the agro-food systems of their territory and can express strong values about them, especially regarding animal welfare in the case of livestock farming.

These values may be misunderstood by agricultural researchers and professionals for whom livestock productivity remains the priority (Appleby et al., 2014; Delanoue et al., 2018). Tensions could then arise and limit the innovation process if the right conditions are not put in place.

In this context, the objective of our study is to evaluate if the inclusion of citizens through co-design in a participatory research project allows the exploration of innovative solutions for agro-food systems. To do this, we implemented a co-design process involving researchers, livestock professionals, and citizens in a participatory research project aiming at producing knowledge and developing innovative solutions for the mountain dairy systems of tomorrow. We used the KCP method because, as previously mentioned, it is known for supporting agro-ecological transitions, building a common horizon, and stimulating disruptive innovation. We hypothesize that the inclusion of citizens through co-design in a participatory research project could play an important role in exploring new solutions provided that tensions between participants do not limit exploration.

2. Material and method

2.1. Study context: the COCCINELLE project

The study takes place within the participatory research project COCCINELLE (CO-Designing with Citizens a New Ecological Dairy Farming in the Mountains), coordinated by scientists, which aims to produce scientific knowledge and co-design innovative solutions for tomorrow's dairy systems in the Massif Central, with a collective of around sixty regional actors. The inclusion of citizens in the project was decided unanimously by the entire project collective but they did not determine how to include them. Their hypothesis, based on empirical elements specific to the agri-food system, were that this inclusion would allow to inform citizens on livestock farming and to better integrate societal expectations in the innovations produced. However, some members of the collective feared that these expectations would not be relevant. The collective has also set itself five major objectives for the dairy farms of tomorrow: respect for the environment, animal health and welfare, product quality and profitability, autonomy and wellbeing of farmers, and links with the territory and society. The design process, composed of a diagnosis and workshop preparation phase and a KCP workshop, was set up 2 years after the start of the project and spanned over a year.

2.2. Diagnosis and workshop preparation phase

Phase D was initiated in April 2021. The main objective was to identify in the Massif Central territory the diversity of expectations of the actors of the territory concerning dairy farming, the relations between actors (in particular the relations between livestock and society), the major actors influencing the evolution of livestock food system practices currently, the type of actors to be included (especially concerning citizens), and the development of a first contact list of participants for the workshop. First, we carried out two focus groups with researchers (one with six researchers working in connection with the territory and dairy farming systems of the Massif Central, the other with two researchers working on animal health and welfare) in April 2021. Second, twenty-nine semi-directive surveys were conducted with citizens and livestock professionals from May to July 2021. Among these twenty-nine respondents, there were twelve citizens: public authorities' actors (local elected officials, national regional park officer), various representatives of civil society (environmental associations, parents' associations, tourist office, association of consumers of organic products), and marketing actors (butcher, cheese maker, alternative store). There were also seventeen livestock professionals: farmers (conventional and organic dairy farmers, beef farmer), actors ensuring coordination (Protected Denomination of Origin association, organic association, Protected Denomination of Origin interprofession, regional dairy interprofession, and mountain farming association), collection actors (Protected Denomination of Origin dairy, conventional dairies), technical advisors (veterinarian, chamber of agriculture, organic association, livestock institute), and actors of agricultural education (agricultural high school). These surveys and focus groups have reinforced the idea that mid-mountain dairy farming is rather idealized by society but still faces multiple challenges such as adaptation to climate change, renewal of generations of farmers and farmer remuneration, considerations related to animal welfare, and health quality of products. Relations between livestock and society seemed less conflictual than in other territories; however, some respondents mentioned some tensions between citizens and farmers or between tourists and farmers. Several livestock professionals have also expressed concerns about abolitionist associations and the image of livestock that they reflect at the national level. In general, livestock professionals indicate that they have little contact with citizens in their work and citizens, even those living in rural areas, have little contact with livestock farmers. A list of potential contacts for the workshop was also formed identifying both actors who are strongly influencing the evolution of dairy farms in the territory as well as actors breaking with the dominant system, possibly bringing new knowledge and different ideas.

These surveys and focus groups helped to choose the subject of the design for the participatory workshop. This subject must be challenging and desirable and the solutions had to be partly unknown. Therefore, we selected as a subject: "A sustainable future for dairy calves". We chose this subject because the current veal calf sector is unsustainable and the French are the highest consumers of veal in the world (FranceAgriMer, 2020). This veal is traditionally consumed white and comes from fattening conditions. On the one hand, this demand for white veal is perceived as an obstacle for the veal industry to change current practices; on the other hand, the current fattening conditions to obtain this white veal are not well known by the citizens (Plan filiére veau, 2017). However, as animal welfare is a growing societal concern (Appleby et al., 2014; Delanoue et al., 2018), the discovery of the current fattening conditions by citizens could stop some of them from consuming veal calves and dairy products. The valuation of veal and dairy products would then be uncertain. This production concerns all kind of dairy systems and its improvement is desirable both by the citizens, concerned about their health and animal welfare, and dairy professionals for whom the acceptability of the practices is essential to keep dairy production. Furthermore, we found it interesting

for the inclusion of citizens because it also questions their role in the improvement of their consumption practices and not only the role of livestock professionals. Indeed, the current veal calf system is an intensive and industrial fattening system, and this type of system aims to perpetuate the existing political economies rather than to provide an effective response to the current concerns (McGregor and Houston, 2018). This kind of system raises many questions in terms of working conditions and remuneration of the farmers, welfare, and health conditions for calves despite recent improvement of the fattening conditions (Ellies, 2014), and a potential health risk for consumers linked to the use of antibiotics (Jarrige et al., 2018) and the potential appearance of zoonoses (Morand, 2020).

Through a literature review (including scientific and technic literature), and a meeting with four experts of the veal calf sector, we identified the major issues and tensions related to the future of dairy calves on farms. The initial subject "A sustainable future for dairy calves" was divided into three themes: (i) Production cycle of dairy cows involving the birth of calves, (ii) Organization of the veal calf sector, and (iii) Veal consumption practices. For each theme, a projector concept was formulated. A projector concept is a verbal proposition whose exploration should make it possible to answer the problem posed. The three projector concepts were (i) "A dairy farming without calves", (ii) "A veal calf sector respectful of human and animal health and welfare", and (iii) "Ethical and responsible veal consumption practices".

For each projector concept, an initial C-K diagram was built. C-K diagrams are diagrams based on C-K theory, a model to understand cognitive activities leading to innovation (Hatchuel and Weil, 2009). C-K theory distinguishes two spaces: a space K of knowledge and a space C of concepts. Space K maps all the knowledge necessary to design an object. Space C is structured as a tree composed of paths representing the undecidable propositions and where each node of the tree corresponds to a partition of the projector concept into several sub-concepts (Agogué et al., 2014). In order to illustrate the operation of the C-K diagram that we used to organize exploration of new livestock food systems with citizens, we take in Figure 1 a simple example: a new camping chair that we want to design. First, we indicate in space K the existing knowledge about our subject. In the case of the camping chair, we see about the context that K1—"Existing camping chairs are heavy and expensive"—and about the properties of the chair that K1 "Chairs have legs." A first operation of the space K to space C from K1 makes it possible to formulate the projector concept "A cheap and light camping chair" which does not actually exist and whose exploration makes it possible to formulate ideas responding to the challenges identified by K1. A new operation of the space K to C from K1 allows the appearance of a first partition of the projector concept in six sub-concepts. Among these concepts there are classic concepts, a chair has one or more legs, but also a disruptive concept that breaks with the current properties of the chair: a chair without legs. The appearance of this concept generates an operation of C to K, leading to the appearance of new knowledge, K2: "Some chairs without feet exist but they are heavy, expensive, and not suitable for camping". Identifying the reason for this, an operation from space K to space C takes place, allowing the contribution of new knowledge K3- "the weight and price are caused by the materials used". A final K-to-C operation allows the formulation of the concept of a chair with very little material. This concept gives rise to the formulation of a new object corresponding to the projector concept: "a, light and cheap chair that allows you to sit cross-legged in a comfortable position, with your hands free, and that can be used everywhere during camping". This new object questions the very identity of the chair. Indeed, the chair is defined as a "back seat", but our object is not a seat and does not have a backrest. It is a strap that connects the back and knees to serve as a support. The structure of the C tree can be qualified by its number of partition levels (in this example three levels) and the expansive character of these partitions. In this example, the first partition is expansive because a concept has given rise to six concepts, the second is restrictive because a concept has given rise to the formulation of a single concept. The three C-K diagrams we built for the workshop had approximately the same structure: the same number of concepts, same number of paths, and the same level of partitions.

Each K space of the C-K diagrams helped us to create a knowledge sheet on each theme. These knowledge sheets are clear and simple to understand, especially for the citizens. A second knowledge sheet was built for each theme with an example of an innovative alternative from another sector to provide original knowledge: the laying hen sector. We also identified a researcher for a first plenary presentation on the links between the environment, human health, and animal health. For each of the three concepts, we built a trend board: a tool that brings together different illustrations linked to the different paths identified on the C tree, to guide participants at the start of the exploration. Each C-K diagram also helped us to identify a new kind of participant that we added to the participant list. For example, the C trees of theme 2 and 3 considered paths linked to human health, so we added doctors to the list of potential participants, or the C tree of theme 3 considered a path linked to the commercialization of meat, so we added a butcher to the list of potential participants.

A facilitation group constituted of eight facilitators (two facilitators who were experts on the theme of dairy farming, two facilitators who were experts on participatory methods, and four facilitators who were experts on the KCP method, Table 1) was formed. The eight facilitators received theoretical and practical training on the KCP method. The facilitation group participated in the organization of the participatory workshop and on the proofreading of the various tools used during the workshop.

The one-day format was chosen based on what had been done in other KCP applications in the agricultural sector (Labatut and Hooge, 2016; Berthet et al., 2020); this format shorter than in the KCP set up in the industrial sector allowed the different participants to be able to free themselves more easily. It was considered to hold the formats in the evening, but we feared that some participants would not be able to be present at the entire design process and would not attend the three steps. It was also considered to hold the workshop on a Saturday so that citizens could come, but livestock professionals and researchers were not available. A communal building was used for the workshop as it was considered a "neutral" location, not belonging to a research institute or to one of the livestock professionals.

For participant recruitment, we selected people from the list of potential contacts. Our objective was to have diverse profiles of participants (gender, age, employment, engagement, and place

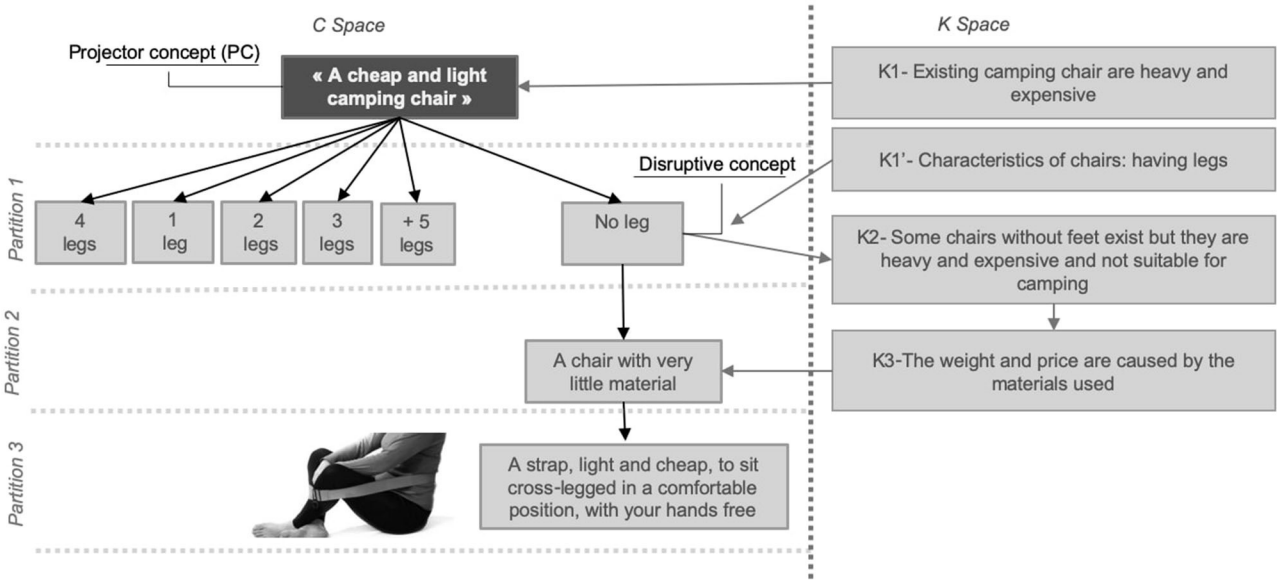

FIGURE 1
Illustration of the operation of the C-K with the example of the conception of a cheap and light camping chair.

of life) without the sample being representative of the diversity of the actors of the territory. A diverse group of researchers, in terms of research disciplines, whose expertise would help with the design, was also recruited. We sought to have researchers who were ready not to take an exclusively expert role but were instead ready to engage with citizens and livestock professionals and listen to them. For livestock professionals, the objective was to have actors from upstream to downstream working for dominant structures on the territory and more alternative structures. For citizens, the objective was to have a diverse group of inhabitants of the territory, in terms of age, gender, consumption habits, expectations, commitment, and profession. We sought to have citizens who could bring original knowledge and ideas to the subject. We also sought to have representative citizens (local elected officials, association representatives) and others who were less engaged. We were open to all types of expectations, except a desire for complete abolition of livestock farming, as we considered it would block any possibility of exploration. As we wanted a maximum of 10 participants in each group and we had three pairs of facilitators available to accompany the groups, we could accommodate a maximum of thirty participants. We employed targeted recruitment through email, phone, or face-to-face. The recruitment of livestock professionals and researchers was relatively fast and most of the people we contacted responded positively. The recruitment of citizens took much longer. The main reasons for not participating given by citizens were the impossibility of making themselves available for a whole day, a feeling of illegitimacy to participate, too little interest in the subject, or the person simply did not respond to the email or phone call. In total, more than 70 citizens were contacted. Twenty-two participants were present on the day of the workshop (Table 1): five researchers from different disciplines (ethology, systemic agronomy, economics, and animal health), eight livestock professionals (farmer, advisors, project manager in an agricultural high school, a veterinarian, interprofession representative, and a butcher) and nine citizens (locally elected, employees of local associations, retirees, translator, IT specialist, doctors, and a communication officer). The age of the participants was between 25 and 70 years old. Gender parity was well respected. Within this collective of twenty-two participants, we created three subgroups, one subgroup per theme, ensuring the diversity of participants within each of the groups.

2.3. The knowledge concept proposal workshop

The workshop took place over a full day during a week in March 2022. For this, we used the KCP method, a method of directed creativity, developed from the C-K theory in order to organize the innovative design with a collective of designers (Zeiler and Savanovic, 2010; Sharif Ullah et al., 2012; Graceraj et al., 2019). It consists of three steps: a phase K of "Knowledge", a phase C of "Concept", and a phase P of "Proposal". During the workshop, the morning was devoted to phase K and the afternoon to phases C and P. In between these phases, the focus was made on informal moments: time to get to know each other, coffee breaks, and shared meals (Figure 2).

The aim of phase K (Knowledge) is to share knowledge, identify missing knowledge, and to identify links between existing knowledge. This phase is essential in order to create a common knowledge base, especially in the case where the designers are diverse and each has very heterogeneous knowledge about the purpose of the design. During phase K of the workshop, a plenary presentation was given by a researcher on the links between human health, animal health, and the overall ecological

TABLE 1 Profiles of the participants and the facilitators and their distribution in the groups.

Code	Category	Employment/ expertise	Engagement
Group 1- Production cycle of dairy cows involving the birth of calves			
Ci-1a	Citizen	IT specialist	X
Ci-1b	Citizen	Employee of a student association	Food waste and solidary association
Ci-1c	Citizen	Local elected	Local elected
Ci-1d	Citizen	Translator	Organic association
Re-1a	Researcher	Ethology	X
Lp-1a	Livestock professional	Dairy farmer	X
Lp-1b	Livestock professional	Dairy advisor	Popular education
Lp-1c	Livestock professional	Project manager in an agricultural high school	Solidarity farming
Group 2- Organization of the veal calf sector			
Ci-2a	Citizen	Medical intern	X
Ci-2b	Citizen	Retiree	Environmental association
Re-2a	Researcher	Animal welfare	Communal association
Re-2b	Researcher	Animal health	X
Re-2c	Researcher	Agroecology	X
Lp-2a	Livestock professional	Agro-environment project manager	X
Lp-2b	Livestock professional	PDO interprofession Technician	X
Lp-2c	Livestock professional	Alternative vet	X
Group 3- Veal consumption practices			
Ci-3a	Citizen	Project manager in the tertiary sector	Solidary and food association
Ci-3b	Citizen	Local product manager	Agricultural association
Ci-3c	Citizen	Doctor	X
Re-3a	Researcher	Economy researcher	Agricultural association
Lp-3a	Livestock professional	Facilitator	X
Lp-3b	Livestock professional	Butcher	butcher association

PDO, Protected Denomination of Origin; KCP, Diagnostic, Knowledge, Concept, Proposal.

state. Then, the participants were divided into three groups. Each group was led by a pair of facilitators (a thematic referent facilitator and a method referent facilitator); two facilitators were responsible for the global organization. Each group was associated with one of the three identified themes. Each participant had an individual knowledge sheet. Then, discussions organized by the facilitators allowed everyone to react to the knowledge of the sheet, express their expectations, or provide additional knowledge. The second knowledge sheet on an innovative example from the laying hen sector was distributed. This sheet was intended to shift the reflections of participants and open up the phase of exploring innovative solutions of the afternoon. During phase K, the facilitators transcribed the key ideas of the exchanges on a poster. At the end of phase K, each group presented to the others the exchanges they had on their subject. Phase K provides common knowledge based on the main challenges to the diversity of participants.

Phase C (Concept), a guided exploration of designers using the C tree of the C-K diagram, was used to generate new concepts and develop solutions from these ideas. During phase C of the workshop, the participants were in the same group as phase K. The key instruction was to explore concepts without taking current constraints into account. The participants had trend boards and Post-its® to explain their ideas. The facilitators were also there to support the formulation of new ideas, identify any fixation effects among the participants, and help them to circumvent these fixations and get rid of natural constraints. The facilitators could rely on the initial C tree of the initial C-K diagram to guide the exploration. The participants did not have access to this tree and the C-K theory was not explained to them. Participants' ideas were organized by the facilitators on a poster.

Finally, Phase P (Proposal) consists of the transformation of concepts into a project aiming at developing a roadmap on the implementation of certain paths explored previously. During phase P of the workshop, the participants, still in the same group, had at their disposal project sheets in order to detail how the ideas explored during phase C could be implemented in the form of a project. In order to select the ideas that the group would develop into a project, they proceeded by voting with stickers. They had two types of stickers available, stickers relating to the relevance of the project and stickers relating to the originality of the project. From the vote, they discussed the ideas they wanted to develop into projects. For each project, the participants had to develop the objectives to be achieved, the actors to be involved, the necessary means, the scale and the time of realization, and the points of vigilance. At the end of phase P, each group presented the result of their reflection during phases C and P to the other actors.

The turns to speak organized by the facilitators, the written materials allowing individual expression, and the effort of popularization of the knowledge by the researchers and the actors of the sector for the citizens allowed the participation of all the actors.

The participants gave their written consent to the use of their personal data and recorded exchanges for research proposes.

2.4. Data analysis

We analyzed the different materials produced during the workshop (K posters, C posters and project sheets) and the videos of the three phases for the three groups. The videos were transcribed using the NVIVO transcription software and then

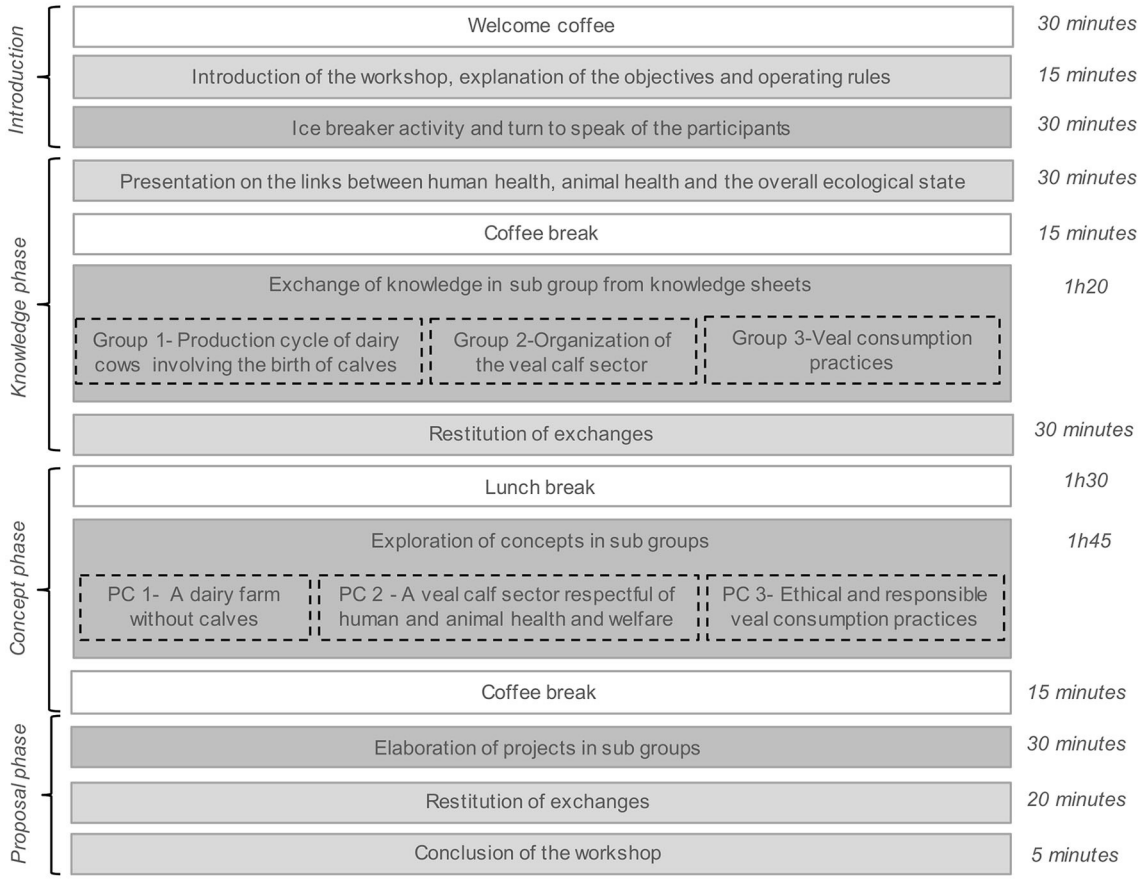

FIGURE 2
Presentation of the course of the workshop. In white is convivial times, in light gray is time in plenary, in dark gray is time in subgroups.

TABLE 2 Criteria used for the evaluation of the C-K diagrams and the projects.

	Variety	Originality
Description	No proliferation of too many similar ideas	Emergence of surprising properties and the renewal of the identity of objects.
Final C-K diagrams	Balanced ratio between height and width; well-distributed concept paths	Large number of expansive partitions on the C tree
Projects	Diversity of objectives, actors involved, scales of achievement.	The projects are linked to disruptive concepts

viewed in order to rectify the script errors made by the software. In the video scripts, we observed (i) the interactions between the participants and especially the number of questions asked by each kind of participants and (ii) the fixation effects (subject of the fixation and the kind of participants who fixated). In the scripts we also identified the knowledge exchanged by the participants which had not been reported in the K poster and the concepts formulated by the participants which had not been reported on the C posters. This allowed us to complete the K and C posters and to build three final C-K diagrams considering the knowledge exchanged between the participants and the concepts formulated. From the project sheets, we built a comparative table of the projects developed. Then, we evaluated the evolution of the C-K diagram and the projects using two criteria: variety and originality (Le Masson et al., 2007; Agogué et al., 2014; Vourc'h et al., 2018). The description of these criteria and the way they were mobilized in our case are visible in Table 2. Figure 3 represents the main steps and outputs of the process.

3. Results

3.1. Production of new knowledge and new concepts through citizen's questions

During phase K and phase C, the citizens were the ones who asked most of the questions to the other participants. In fact, approximately 63% of the questions were asked by citizens with some variation between the groups (Table 3). Many of these questions can be related to the generative design questions identified by Eris (2003). We identified (i) "Negotiation questions" when the questioner wanted to suggest a concept, or to negotiate an existing or previously suggested concept, for example: Ci-1c-"*And why do we separate them (cow and calf), we couldn't*

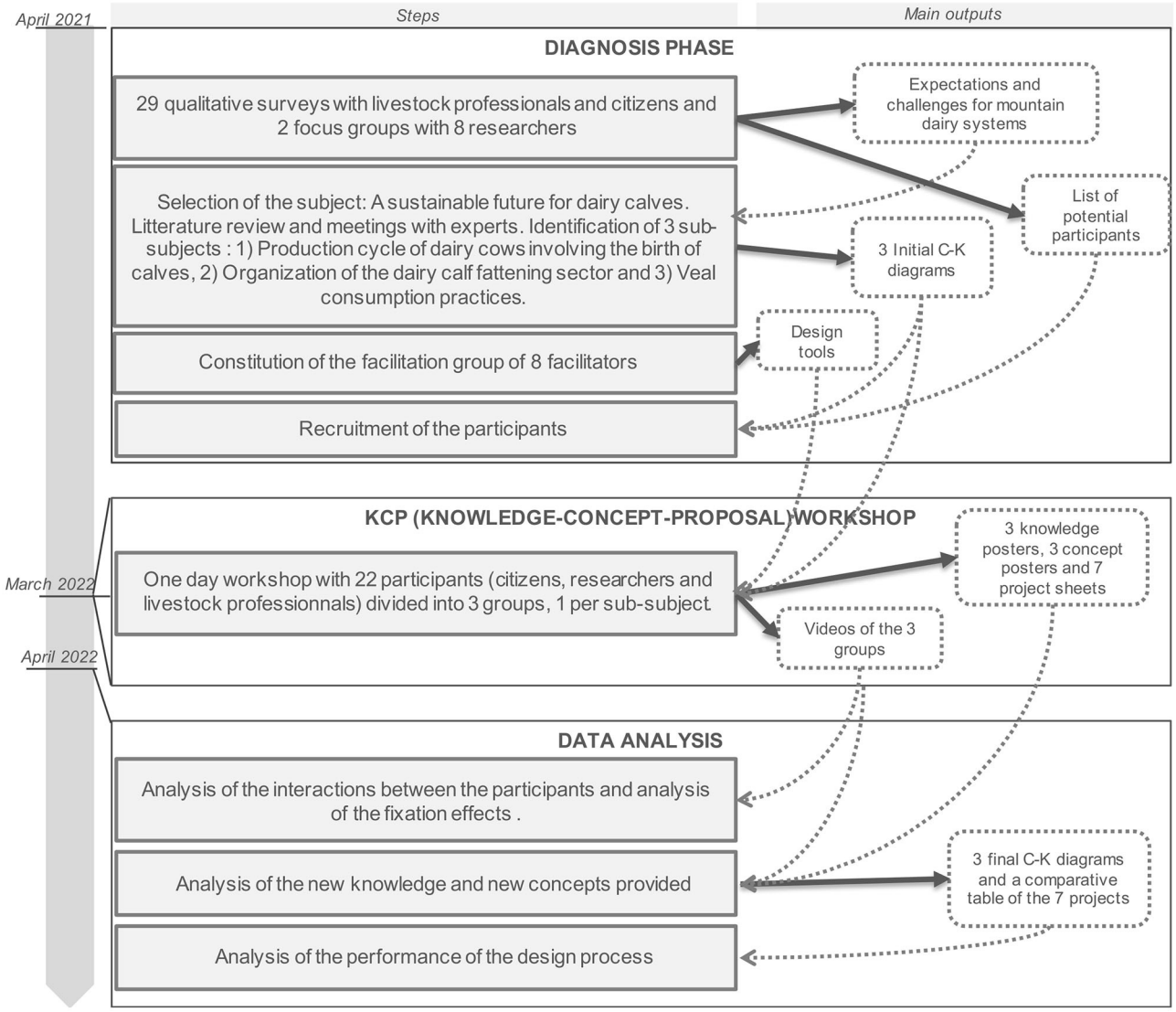

FIGURE 3
Steps and main outputs of the design process. Solid arrow: output generated by the step, dotted arrow: output mobilized for the step.

leave them together?", (ii) "Scenario-creation questions" when the questioner constructed a scenario involving the question concept and wanted to investigate the possible outcome, for example: Ci-1d-*"Can we imagine relocating fattening on the territory?"*, (iii) "Ideation questions" where the questioner wanted to generate as many concepts as possible from an instrument without trying to achieve a specific goal, for example: Ci-2b-*"But what exactly is a farm? What's the point?"*, and (iv) "Enablement questions" where the questioner wanted to construct acts, states, or resources that could enable the question concept, for example Ci-3a-*"How can we educate consumers upstream?"* These questions brought new knowledge not identified in the initial C-K diagram and therefore not provided to the participants via the knowledge sheets and the plenary presentation. Sometimes these questions also allowed the identification of collective knowledge gaps (the group of participants identified that the knowledge they needed to answer was missing). Examples below show how knowledge produced through citizen's questions and missing knowledge was used to formulate new concepts during phase C, allowing completing the C tree of the initial C-K diagrams.

In group 1, the citizens were the only participants to ask questions (Table 3). These questions concerned current agricultural practices (mother-calf separation, reproduction and health, and fattening region) as well as potential alternative practices (farm fattening, modification of the production cycle, and reduction in the number of births of male calves). The livestock professionals and the researcher answered these questions providing new knowledge for the participants, not present in the knowledge sheets. This knowledge was often used to formulate new concepts (Figure 4). For example, one citizen asked a question about the possibility to modify the production cycle. A livestock professional answered it was possible, but the risk is a reduction in milk production. Later on, another citizen question allowed a contribution of knowledge on a negative correlation between cow

TABLE 3 Number of questions asked by category of participants during phase K and C.

	Group 1-	Group 2-	Group 3-
Composition of the group	4 citizens, 1 researcher, and 3 livestock professionals	2 citizens, 3 researchers, and 3 livestock professionals	3 citizens, 1 researcher, and 2 livestock professionals
Number of questions asked by citizens	29	19	16
Number of questions asked by researchers	0	12	9
Number of questions asked by livestock professionals	0	7	10

health and a high production level. During phase C, the participants started to consider a decrease in milk production. However, for some of them a decrease of milk production was not conceivable as it would reduce the income of dairy farmers, which is already very low. Therefore, the participants considered an initial solution of producing something else on the dairy farm to compensate for the decrease in milk production with a concept of "a plant production for human consumption, produced in addition on the dairy farm" and a second solution to improve the income of dairy farmers with the concept of "a good remuneration of the milk".

In group 2, the citizens were not the only ones to ask questions, but they were the ones who asked most of them (Table 3). Their questions concerned the reason for current practices (use of antibiotics, slaughter of young animals), the impact of these practices on health (possibility of zoonoses), and the relevance of a new alternative practice (association of animal species). As in group 1, the livestock professionals and the researcher answered these questions providing new knowledge often used to formulate new concepts. For example, a citizen asked a question about the relevance of an association of animal species as in permaculture; a researcher answered that he knew about an experiment by German researchers on an association between chicken and cows for predation and parasitism. Other participants admitted that incorporating diversity into animal production systems can be good to increase resilience. Indeed, we can find in the literature that it has been developed before (Dumont et al., 2020). However, the participant did not know the benefits it could have in the case of the veal calves because it had not been tested yet with this type of animal. This knowledge and missing knowledge allowed the formulation of the concept of "a permaculture of calves" leading to two new concepts proposed by participants in this group: (i) "domestic and wild diversity on the farms" and (ii) "Environmental symbiosis" (Figure 5).

In group 3, as in group 2, the citizens were not the only ones to ask questions, but they were the ones who asked most of them (Table 3). Citizen questions concerned the difference between the labels, the reliability of the organic label, and the means of raising consumer awareness. All types of participants answered these questions and provided knowledge often used to formulate new concepts. For example, citizens' questions about the reliability of the different labels and the difference between them led to knowledge on the different kinds of labels and the observation that some labels are better known than others. For example, the different kinds of eggs, namely "organic", "outdoor access", and "cage", are well known by consumers. Therefore, the participants considered a concept of "a simple label for veal such as eggs" (Figure 6).

These various examples show that citizens' questions were essential to provide new knowledge and new concepts, especially citizens asked most of the questions in the three groups.

3.2. Fixation effects are reduced by mixing groups of actors

The heterogeneity of the actors allowed to counteract the fixations in the three groups. Across the three groups, we observed that livestock professionals and researchers were fixed by the idea that calves have to be killed and become meat. On the contrary, some citizens considered not killing the animals. In group 2, a citizen was even fixed by this idea during most of the phase C Ci-2a – "*What bothers me is that we are still in the slaughter of animals, for me we polish the edges, but it stays the same*". At another point in time, the participant indicated that considering the animal only from the angle of profitability bothered her Ci-2a -"*What questions me is the profitability of the living. The animal is only a product and is never considered as a living being. It's a product and that's all.*" Later, she proposed the idea of a retreat area where the calves could finish their lives and where they would be considered for something other than a product. When she saw her idea was not shared by the others, she did not speak for 1 hour. On the contrary, the livestock professionals and the researchers, did not consider a farm without slaughtering at all. Even a fattening of all the calves until adulthood was only discussed a little bit and was quickly abandoned. Some of them evoked the question of a higher cost and a higher carbon impact as reasons against these ideas. Some of the participants considered fattening until a different age stage, mainly to meet consumer expectations while considering economic and environmental constraints. In group 3 we observed the same opposition of fixation between a citizen and the other kinds of participants. The citizen said that she was unable to eat young animals and other participants tried to show her that it is not a consistent behavior because a lot of animals are eaten young (chickens and pigs). At no time did they question the slaughter of calves despite the group's objective of considering more ethical consumption practices. This occurred to a lesser extent in group 1; one citizen proposed the concept of using the calves for environmental services without specifying what will happen to these calves at the end. During phase P, this concept was chosen for a project. The researcher and two livestock professionals immediately added the condition of killing the calves for meat at the end without letting the citizen express themselves on it.

We also observed a difference of fixation among actors on other subjects. In group 1, for example, several livestock professionals and a researcher were fixed by the existing organization with the dairy sector on one side and the beef sector on the other. Re-1a- *"Yes but, the abolition of the beef sector is a bit radical...."* Lp-1a– "*A little radical, next time invite beef farmers they will be happy !*" The citizens did not see the interest in maintaining the two sectors and

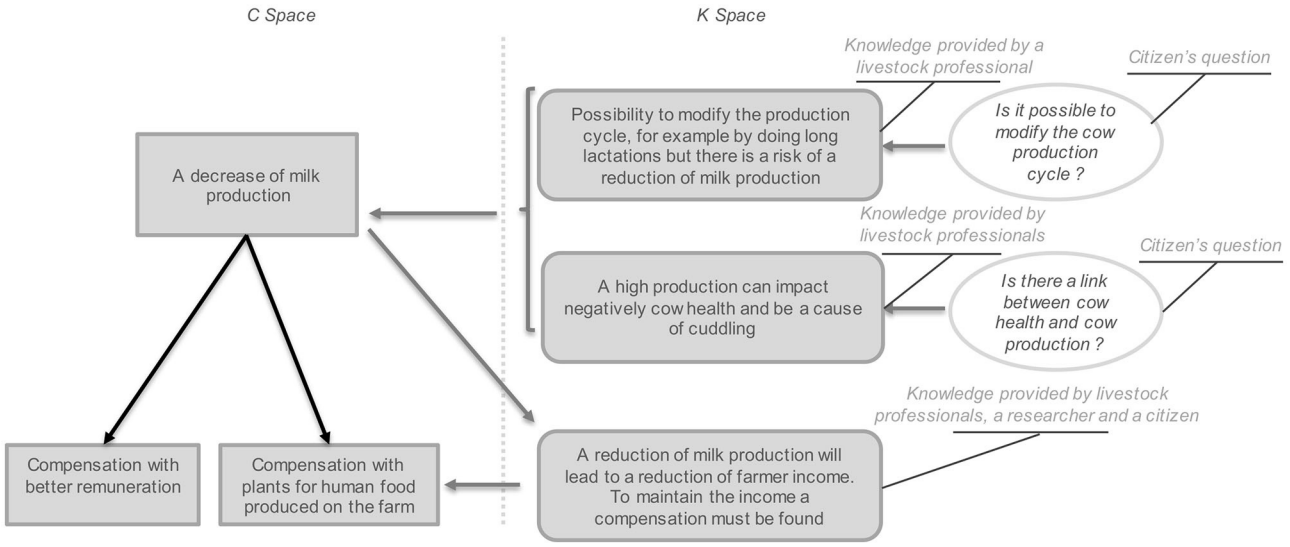

FIGURE 4
Example from group 1- "Production cycle of dairy cows involving the birth of calves" showing the link between citizen's questions, new knowledge, and the production of concepts. White ellipse: citizen's questions, light gray rounded rectangles: knowledge, light gray rectangles: concepts.

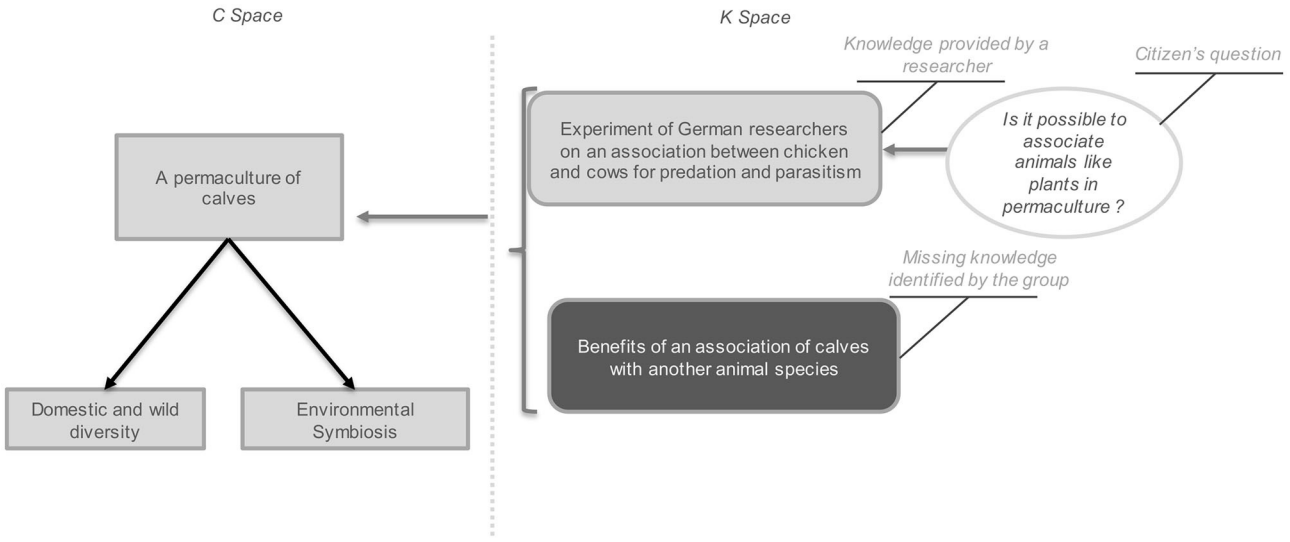

FIGURE 5
Example from group 2- "Organization of the veal calf sector" showing the link between citizen's questions, new knowledge, and the production of concepts. White ellipse: citizens' questions, light gray rounded rectangles: knowledge, dark gray rounded rectangles: missing knowledge, light gray rectangles: concepts.

proposed solutions around the development of a mixed meat and milk sector. In group 2, some livestock professional and researchers were fixed by the idea of letting the calves inside Re-2b - *"the problem with putting them on the grass is that you have to have the surfaces to put them in. There are questions about the fences... we want to keep them in the building because it's easier to manage! What we can consider is offering them grass or hay to eat instead [of milk powder but keeping them inside]"* whereas the citizens immediately considered the idea of letting the calves have outdoor access.

In groups 1 and 2, participants did not stay fixed by the same idea for a long time. However, in group 3, all the participants were fixed during most of phase C on solutions relating to the improvement of communication and consumer education. A researcher said Re-3a—*"What is innovative is communication [. . .] The consumer must understand the producer's constraints. Communication is essential, each of the players must fully understand the constraints of the others."* For a citizen it was really important to educate consumers and for a livestock professional it was essential to figure out how to get people to change their minds to encourage them to get meat from local traders who can raise awareness about the different products and sell the best quality rather than going to supermarkets.

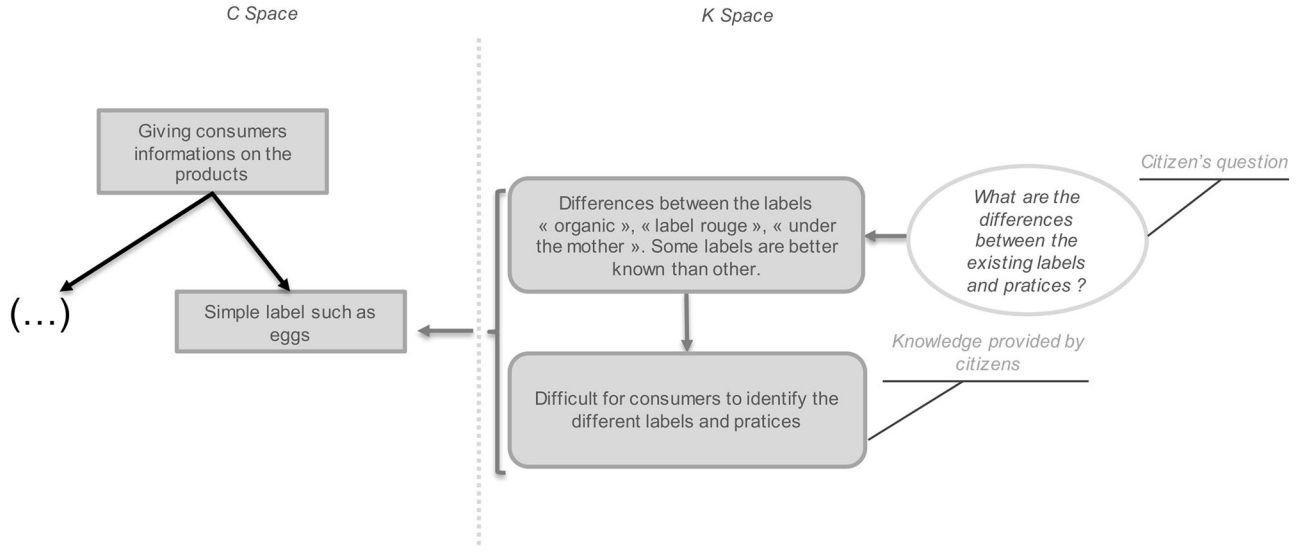

FIGURE 6
Example from group 3- "Veal consumption practices" showing the link between citizen's questions, new knowledge, and the production of concepts. White ellipse: citizens' questions, light gray rounded rectangles: knowledge, light gray rectangles: concepts.

3.3. Evaluation of the exploration: variety and originality of the new concepts created

During phase C, the participants proposed both varied concepts as well as original concepts by attributing surprising properties to their design subject and by renewing the identity of certain objects. In fact, the three groups completed their initial C tree with new paths and new concepts. The three final C trees show a good distribution of conceptual paths and a large number of expansive C partitions.

For group 1, the paths of the initial C tree go mainly up to three levels of partitions and one up to four, whereas most of the paths of the final C tree go until four levels of partitions, some up to five, and one up to six. The final C tree also kept a good distribution of paths in width. A lot of partitions are expansive: most concepts formulated led to the formulation of at least two other concepts. Only one partition was restrictive: the concept "a computer prediction to maintain long lactation" led only to "a prediction by machine learning". Some concepts have surprising properties and allow a renewal of the identity of the designed objects. This is the case, for example, for the concept of the development on dairy farms of plants for proteins that can be used directly for human food. The dairy farm is assigned a new property, protein intake, whether animal or plant-based, and not only milk production. We can also quote the concepts of using calves for "education", "traction", and "environment maintenance". All these concepts represent new properties attributed to the calves, usually only intended for meat production (Figure 7).

For group 2, the C tree from the initial C-K diagram focused on two main paths: a path on the improvement of the current veal calf sector and a path on the fattening of calves on dairy farms. The participants added a totally new path about a new fattening sector different from the two other paths considered on the initial C-K diagram, allowing an enlargement of the tree. The participants focused more on the new path, considered more disruptive and pertinent that the two other paths. Indeed, the current veal calf sector has already been improved several times (for example, improvement of the space per calf through new regulations via the European council directive 97/2/EC), but for the participants it was not disruptive enough to solve all the challenges identified and improve the global sustainability of this system. They considered it necessary to question the system as a whole. The second path of "Veal calves fattening on the dairy farms" is more disruptive but already developed by farmers; through experiments on farms, it does not seem to be easily replicable on every farm, mainly due to labor issues. Therefore, the participants spent more time developing concepts around the path of "a new fattening sector". This path has five levels of partitions and all the partitions are expansive and attribute new different properties to the fattening sector (environmental symbiosis, cooperation between dairy farmers, valorization of culled cows, etc.) (Figure 8).

For group 3, compared to the other groups, fewer concepts were added to the initial C tree of the C-K diagram. The final C tree is, however, quite well balanced in width and height. Some paths have four levels of partitions. Regarding originality, all the partitions are expansive and some concepts assign surprising properties to the designed object. This is the case with veal consumption consistent with seasonality, which is not currently the case for meat, whereas it is very widespread for the consumption of fruit and vegetables. The last path, "Citizen actors of change beyond their consumption", considered in the initial C-K diagram deserved to be further developed because it was the most disruptive path: it breaks with the existing ways of acting of the citizens and makes it possible to question the role of the citizens beyond their consumption

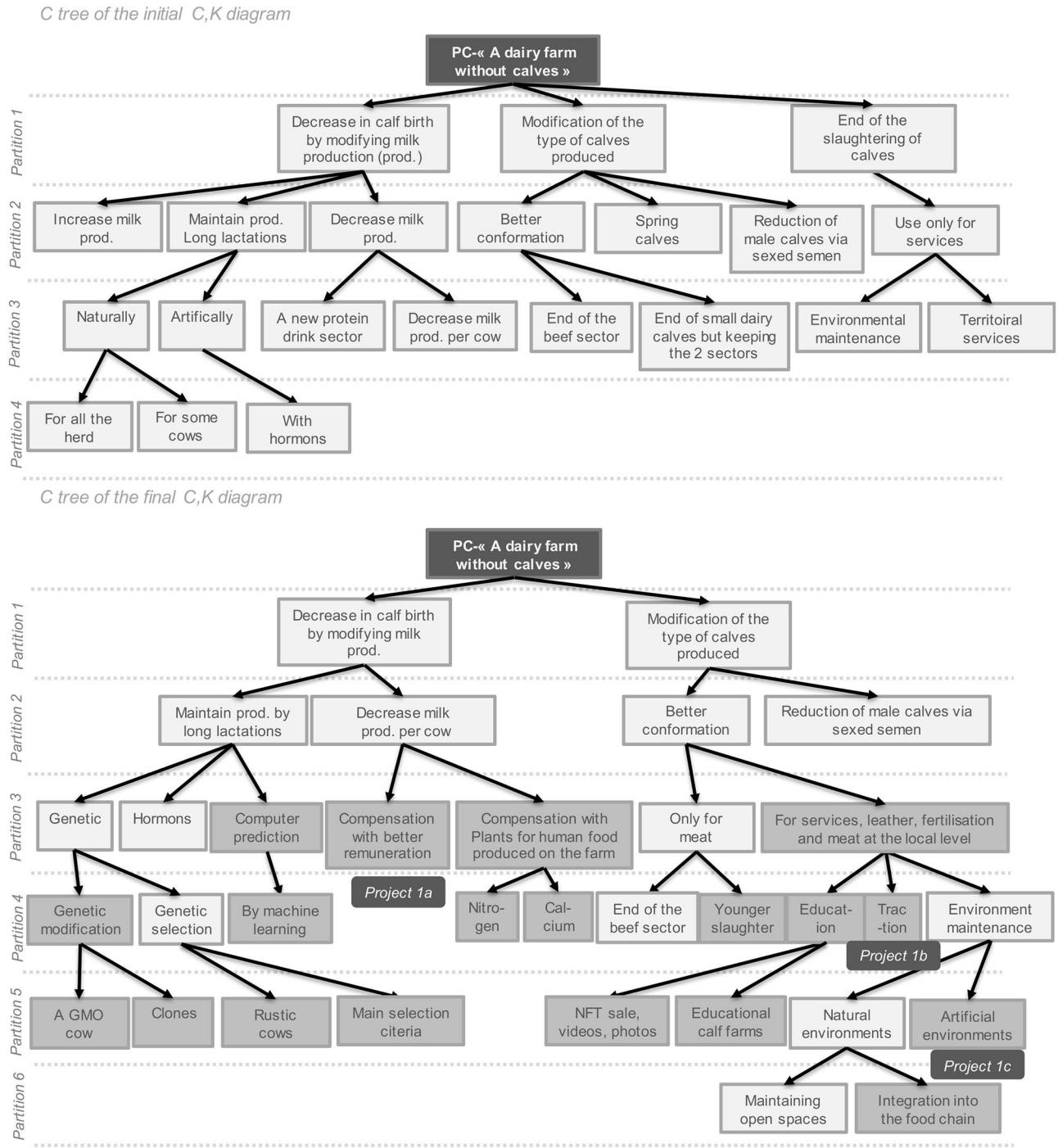

FIGURE 7
Evolution of the C trees from the initial C-K diagram to the final C-K diagram of group 1 for the PC- "A dairy farm without calves". Light gray rectangles: concepts already considered on the initial C-K diagram, gray rectangles: concepts considered during the workshop, dark gray rectangle: projector concept, dark gray rounded rectangles: projects developed.

habits. However, the participants were fixed by the first two paths (Figure 9).

The structure of the final C-K diagrams shows that the participants of three groups provided varied and original concepts that were not considered on the initial C-K diagrams.

3.4. The transformation of new concepts into original projects

During the third phase of the workshop, phase P, participants came up with ideas and projects to realize some of the concepts they came up with. These projects can potentially be taken up

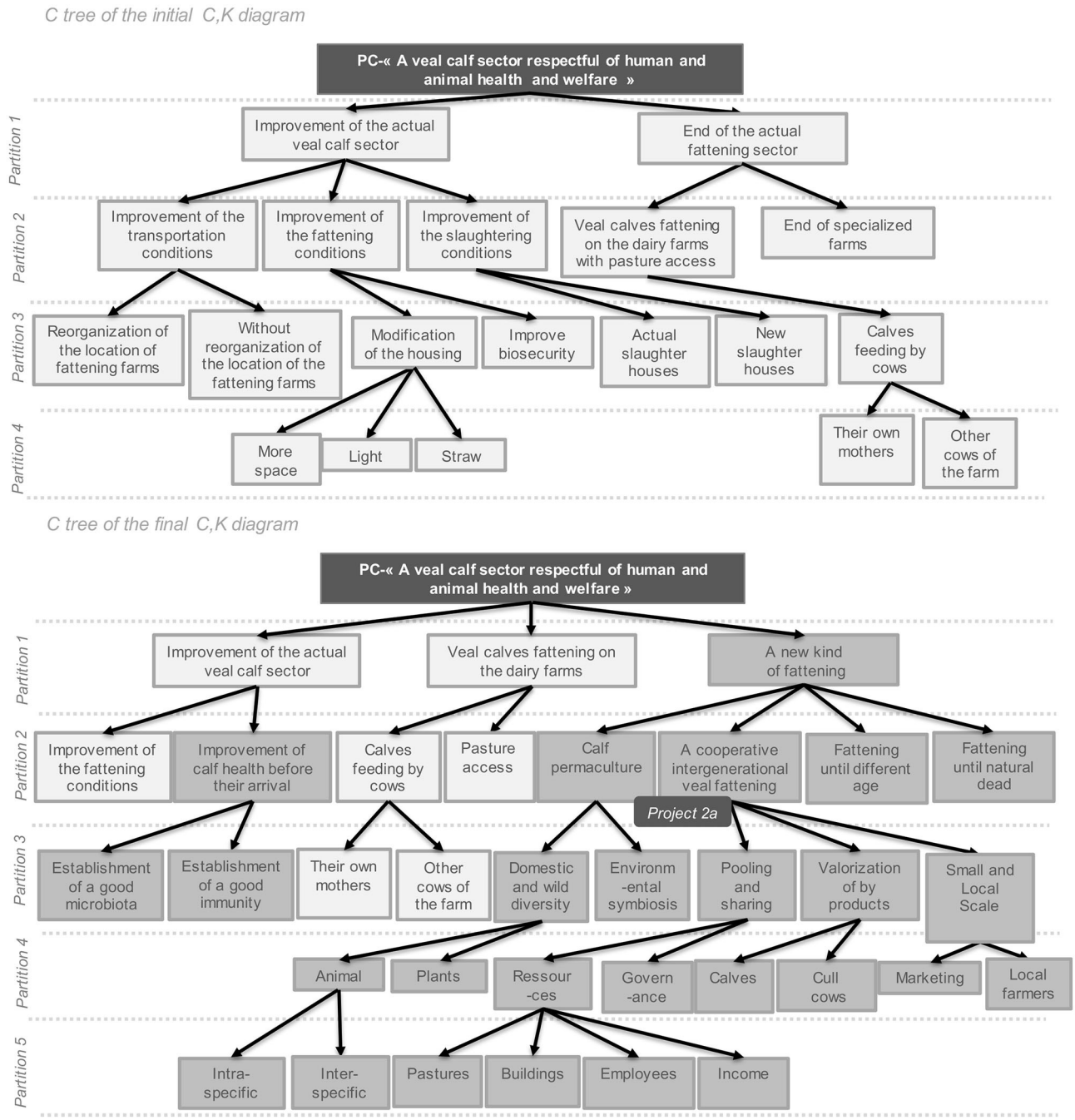

FIGURE 8
Evolution of the C trees from the initial C-K diagram to the final C-K diagram of group 2 for the PC- "A veal calf sector respectful of human and animal health and welfare". Light gray rectangles: concepts already considered on the initial C-K diagram, gray rectangles: concepts considered during the workshop, dark gray rectangle: projector concept, dark gray rounded rectangle: project developed.

by participants or inspire them to change some of their practices following the workshop. The participants proposed a total of seven projects (Table 4). These projects involved a diversity of actors (farmers, cereal growers, foresters, veterinarians, butchers, state, local authorities, consumers of animal products, citizen associations, natural parks, etc.), developed various scales of implementation (local, national, and continental), and various objectives (new cooperation between players, price setting, use of calves for other services, new labeling, awareness, system allowing access for all to quality products). Projects are associated with varied concepts for groups 1 and 3 (Figures 7–9), or associated with the most disruptive path, group 2. Projects are also innovative

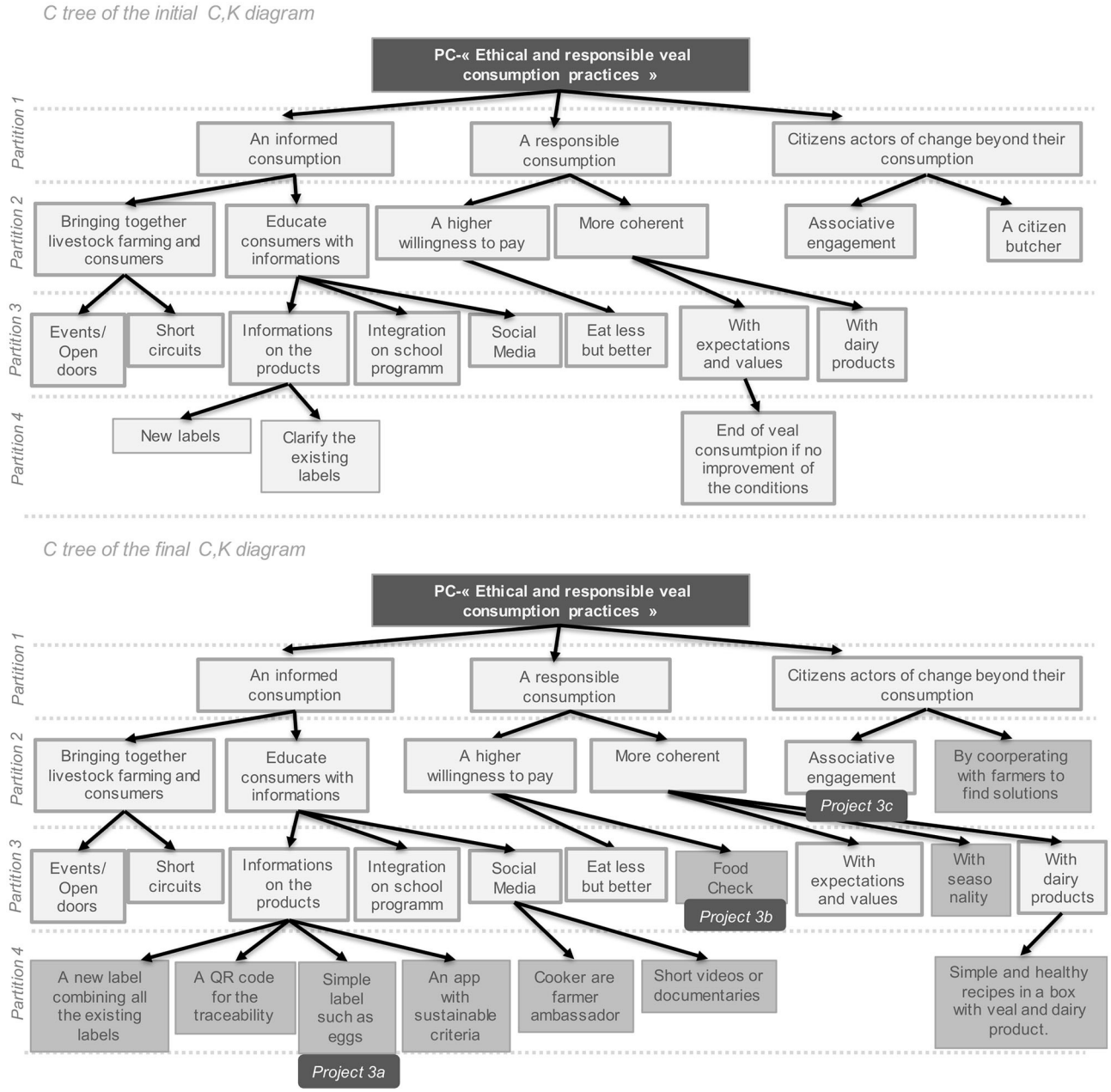

FIGURE 9
Evolution of the C trees from the initial C-K diagram to the final C-K diagram of group 3 for the PC- "Ethical and responsible veal consumption practices". Light gray rectangles: concepts already considered on the initial C-K diagram, gray rectangles: concepts considered during the workshop, dark gray rectangle: projector concept, dark gray rounded rectangle: project developed.

because they allow the inclusion of non-traditional stakeholders and assign new roles to certain actors. For example, in certain projects, citizens have a role beyond the simple consumption of products (dissemination of information, support for farmers, etc.). Some projects also consider new collaborations between actors who are not involved in collective action yet, for example cereal farmers and dairy farmers or dairy farmers among themselves to develop together a veal fattening sector.

4. Discussion

4.1. Main contributions for the literature on agro-food systems, citizen sciences, and co-design

In order to evaluate if the inclusion of citizens through co-design in a research project on future livestock systems

TABLE 4 Description of the projects considered during the workshop.

Project	Title	Objectives	Actors involved	Scale
1a	The right price	Significant increase of the milk price allowing a reduction of the dairy herd and of the number of calves, either naturally or via milk quotas.	Government, communities, citizens	Local, national or continental
1b	The useful beef	Lower cost animal produced on grass and providing useful services in addition to their meat value: maintenance of plant cover in depreciated areas, skidding, traction in areas difficult to access.	Farmers, foresters, researchers, veterinarian, citizens	Local on multiple territories
1c	Dairy and cereal farmer cooperation	Use of male calves in summer in mountain pastures or pastures that are not exploitable and in winter in the plains to enhance the plant cover of cereal growers and for organic fertilization.	Farmers, cereal growers, technical advisors, butchers, citizens	Local on this territory
2a	A cooperative intergenerational veal fattening	Veal calves raised by nurse cows intended for culling, by a local cooperative composed of dairy farmers, valued on the site in a short circuit.	Farmers, an ethical committee of citizens, butchers	Local on different territories
3a	Who am I?	A simple label that informs about the fattening method: type of milk used and housing. Added to existing labeling.	Government, citizens.	National
3b	Pink veal check	A check for modest income to access quality veal, ethically raised, fed with breast milk. Promote virtuous practices for the calves and the farmer.	Government, farmers, butchers, citizens	National
3c	Veal Association	Implementation of actions in existing consumer association to raise awareness of veal calf fattening practices and the nutritional qualities of products	Consumer association, Meat interprofession, citizens	Local on different territories

allows the exploration of innovative solutions, we mobilized the design method KCP with a collective of researchers, livestock professionals, and citizens on the subject of a sustainable future for dairy calves. We have shown that the participation of citizens during this design process led to the exploration of solutions for this livestock food system because it allowed the contribution of new knowledge and because citizens were less fixed by the current context. In fact, the lack of expertise of citizens on livestock production conduced them to ask questions to the other participants. A lot of these questions were generative design questions (Eris, 2003) and led to the contribution of additional knowledge, allowing the expansion of the knowledge available on the subject in the design group. Some of this knowledge led to the formulation of new concepts. In addition, in some cases, the other participants were not able to answer citizens' questions. Collective "knowledge gaps" were then identified. According to the literature, these collective "knowledge gaps", if they are properly managed, allow the exploration of new solutions and the countering of certain fixations (Roberts, 2013). The management of these "knowledge gaps" being at the heart of KCP's objectives (Berthet et al., 2016), we have shown that their identification encouraged the exploration of innovative solutions during the workshop. Furthermore, in line with our hypothesis, citizens are less influenced by the current organization of the livestock sector. We have observed fewer fixation effects from citizens when they explore new solutions than from livestock professionals and researchers who have often been fixed by the constraints and the current organization of the livestock sector. This confirms what is often observed in methodologies aimed at innovative design. Participants are often blocked by the basis and structure of their initial knowledge, which can negatively impact creativity (Abraham and Windmann, 2007; Le Masson et al., 2011; Agogué et al., 2014). The lesser level of fixation of citizens allowed them to question the primary identity of the livestock food system: the slaughter of animals. Some citizens considered the idea of not slaughtering calves or at least the idea of considering them not only as meat, whereas this idea seemed unthinkable for livestock professionals and researchers.

Our results are consistent with the literature on co-design. The participation of citizens, although they are not direct users of the innovations produced for agroecosystems, has allowed the proposal of innovative ideas and concepts as was shown when users are involved in a design process (Steen et al., 2011; Mitchell et al., 2016; Trischler et al., 2018). However, we found that citizen participation in exploration was lower when the design theme was directly related to their consumption habits, whereas in this case, they were direct users of the innovation produced. They were much more easily fixed on this subject than the citizens of other groups for whom the subjects were far from their daily life and knowledge. This suggests that the method used and the question-asking mechanism may not have been appropriate in this case.

Our work can also contribute to the fields of citizen science. Indeed, the main interests identified in the literature, the participation of non-scientists in a research process are, as indicated in the first part of the article (i) the production of knowledge that could not be achieved otherwise (Devictor et al., 2012; Jankowski and Le Marec, 2014; Chandler et al., 2017), (ii) a more socially relevant science through better understanding of field problems by researchers (Johnson et al., 2004; Cornwall, 2008; Waddington et al., 2014), and (iii) a development of participants' skills (Sumberg et al., 2003; Brossard et al., 2005; Luneau et al., 2021). But we have shown that citizen participation can also contribute to the exploration of innovative ideas and concepts, which is relatively underexplored in this literature.

4.2. Factors that contributed to the success of the design process

The KCP method was designed to circumvent the fixation effects, thus creating a framework for exploration. Moreover, the facilitators were well trained in this method and thus were able to best accompany the exploration process. However, various adaptations were necessary in order to allow the participation of citizens with little knowledge about livestock farming and values sometimes contrary to those of other participants. Without this, citizens might not have felt able to express themselves and felt comfortable participating. First, a special focus was made on the interactions in an atmosphere of trust. Convivial activities had a very important role between the participants for mutual knowledge. We limited the plenary sessions by favoring subgroup sessions whereas design methods do not always include time dedicated to knowledge exchange (Berthet et al., 2016). Instructions were given alongside reminders encouraging respect for all points of view. The facilitators in pairs were responsible for distributing the floor as well as possible and mitigating conflicts if they arose. This was very useful in some cases, particularly when some citizens proposed the idea of no longer slaughtering animals, as this idea was not shared by livestock professionals. The facilitators regulated the interactions so that all ideas were considered and reminded participants that the goal was to explore a variety of concepts and not necessarily to reach a consensus that works for everyone. Tools were built to be accessible to all. The knowledge sheets were designed to be understandable by citizens with little knowledge on the subject, which is essential to facilitate the acquisition of new knowledge in order to equip the members of a collective with new creative capacities (Laousse and Hooge, 2018). The projector concepts were understandable by all actors. In manufacturing, the concepts used are often very disruptive and offbeat in order to best circumvent fixation effects. In our case we wanted the issue to be clearly identifiable by everyone through the concept. Similarly, the project sheets were simple and clear with an accessible vocabulary.

The profiles of citizens participating in the process were diverse, which was useful for exploration because they had different questions and different ideas. In addition, the participants present were relatively open to exchanges, which greatly contributed to the atmosphere of goodwill at the workshop.

4.3. Reflection on methodology

In this study we mobilized the KCP method, developed especially to circumvent fixation effects, and we made sure to adapt it in order to allow citizen participation. We cannot therefore guarantee that all co-design methods would have produced similar results. In any case, it seems important to us to adapt the existing methods in order to promote the expression of citizens in this particular context of agro-food systems.

Furthermore, even though the profiles of citizens participating in the process were diverse, we did not have a representative sample of the diversity of citizens in the territory. The citizens were all a little aware of the agricultural challenges. This was not an objective during the recruitment, we were also looking to have citizens far from this environment, but it turns out that the workshop attracted people interested in the subject and therefore with a minimum level of awareness. Moreover, most of the participants of the workshop were open to exchange and we chose not to include citizens against the very existence of livestock farming in order to avoid conflicts because some livestock professionals had quite virulent remarks made about them during the diagnosis phase and did not want them to be present during the workshop. Vegan citizens and members of abolitionist associations would indeed have supported more strongly the idea of the end of animal slaughter. This could have possibly challenged livestock professionals and researchers on the idea that livestock food system is inseparable from slaughter, and they could propose solutions that were even more innovative. However, conflicts could have arisen between the participants and hindered exploration. Thus, we cannot conclude that the results observed could have been observed with any citizens.

4.4. Perspectives

In this article, we contribute to the evaluation of the interest of citizen participation through co-design in a participatory research project on future agri-food systems. We have shown that the inclusion of citizens by co-design makes it possible to highlight a new interest in the inclusion of non-academic actors in a research project: the exploration of innovative ideas. It would be interesting, however, to study whether the inclusion of citizens, in this way, makes it possible to produce knowledge that could not otherwise be produced, to develop a science that is more socially relevant and leads to an increase in the number of citizens. Moreover, if this is the case, it would be interesting to study the underlying mechanisms. This would ensure, in particular, that citizens are not only instrumentalized to generate innovations but that they can also benefit from this process.

In addition, this article seems to open perspectives for further research in co-design. It would be interesting to study whether this type of device can generate the development of sustainable innovation communities over a long period of time as was the case for Laousse and Hooge (2018) or whether this device is intended to be specific? Moreover, as the question-asking mechanism seems crucial to explore new ideas, what variants of KCP could be developed to help citizens formulate generative design questions? It may also be relevant to consider whether this type of process can be put in place in the case of very strong value conflicts between livestock professionals and some citizens. And if so, what type of co-design method would be suitable?

Our work is a first step in showing the value the inclusion of citizens can have in agro-food systems evolution. We have shown how mobilizing citizens through design using an adapted method can be an opportunity for increasing exploration and creativity, very much needed in addressing actual grand challenges in food systems' research. Further research is needed, and this first experience should now be tested for a higher variety of agro-food systems, a variety of citizens, and different kinds of co-design methods.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Funding

This research is the subject of funding from the metaprogram SANBA (Health and welfare of farmed animals) and the French government initiative IDEX-ISITE 16-IDEX-0001 (CAP 20-25) within Philippine Coeugnet's Ph.D., thesis, and the Ministère de l'agriculture et de l'alimentation (MAA)-convention Massif central 2015-2020 within the COCCINELLE project (CO-Designing a New Ecological Mountain Dairy Farming with Citizens).

Acknowledgments

We would like to thank the metaprogram SANBA, the French government initiative IDEX-ISITE 16-IDEX-0001 (CAP 20-25), and the Ministère de l'agriculture et de l'alimentation (MAA)-convention Massif central 2015-2020 for supporting the PhD thesis and the COCCINELLE project. We would like to extend our gratitude to the twenty-two participants of the workshop and Chantale Chassaing, Chloé Salembier, Matthieu Bouchon, and Marie Taverne for their help during the workshop. Special thanks is given to Juliette Baste Morand for her precious help in the recruitment and the organization of the workshop. We also thank IDEAS (Initiative for Design in Agrifood Systems) and especially Laura Le Du and Thibault Lefeuvre for their help during the preparation of the workshop and for the training of the facilitators. We would also like to thank Allison Loconto for her help and insightful reading of our article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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