# Development and validation of an automatic and intelligent system for medullation and average diameter evaluation to Alpaca, Llama and Mohair fibers

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***Abstract*—The aim of this work was to develop and validate an automatic and intelligent system (based in artificial intelligence) capable of quantify and identify fibers, by type of medullation in 5 categories. This work was carried out in Lima, Peru. To develop the software a trained model was generated based on You Only Look at Once for medullation and DenseNet for average fiber diameter (AFD), using Python. Language C was used to develop the graphical user interface. For the hardware; mechanical, electronic and optical subsystems was design and development. Samples of white alpaca, llama and mohair fibers (2108, 1858, 901 fibers, respectively) were evaluated for identification the fibers medullation. Additionally, AFD of 197 samples of white alpacas were measured with two methods. This system identifies 5 types of medullation and measures the diameter of the fibers. Each sample is evaluated in 40 sec, considering about 1500 fibers/sample. At two-proportion z-test of different fiber medullation types obtained with direct counting and our system no significant differences were found. At t-test of AFD obtained with OFDA device and our system no significant difference were found. The relationship between these methods was very stronger (r=0.95). The use of this system is recommended for fiber evaluation for the purpose of genetic improvement of fibers in animal production; purchase-sale, and processing of fiber to verify the quality of fibers; and research on medullation to increase knowledge about alpaca, llama and mohair fibers.**

***Keywords*—Alpaca, Fibers medullation, Artificial intelligence.**

## I. Introduction

The reduction or elimination of strongly medullated fibers (or objectionable fibers), and continuous fibers of the mohair, alpacas and llamas, is imperative, because these fibers constitute a problem for animal production and the textile industry [1]. Therefore, it is essential to have a practical procedure for the identification and quantification of these fibers. The objective method used to measure incidence medullated fibers – Projection microscopy (PM) – is not practical because it is laborious, expensive and time consuming [2], and others methods are neither exact or precise [3]. For these reasons, the present work was carried out with the aim of developing and validating an automatic and intelligent system (based in artificial intelligence [IA]) capable of quantify and identify fibers, by type of medullation in five categories [Non medullated (NM), Fragmented medulle (FM), Uncontinuously medullated (UM), Continously medullated (CM) and Strongly medullated (SM)] and to measure average fiber diameter (AFD) of each of these categories.

## II. Materials and methods

### A. Location

This technological development was carried out in Lima, Peru.

### B. Model development using Artificial Intelligence (AI)

To develop AI-based software (capable to identify fibers by medullation type and to measure AFD), a trained model was generated based on "You Only Look at Once" (YOLO) for medullation and DenseNet for AFD, using Python and the Pytorch framework. Programming language C ++ and C # were used to develop the graphical user interface (GUI).

### C. The hardware for use of AI-based software

For hardware development, three sub systems were considered: mechanical, electronic, optical. Autodesk Inventor program was used for the design. Later, some pieces were printed in polylactic acid (PLA) and resin with 3D printers and the others mechanized in different machines. Hardware and software was called IA-Fiber Med system (IA-FiMeSy).

### D. Samples preparation

Samples of white alpaca, llama and mohair fibers (2108, 1858, 901 fibers, respectively) were evaluated about identification fibers according medullation type with direct counting (DC) and IA-FiMeSy) methods. Additionally, AFD of 197 samples of white alpacas were measured with OFDA and IA-FiMeSy methods. Z-test. T-test, correlation analysis and linear regression were used to compare results obtained from medullation and AFD with IA-FiMeSy and other methods (DC and OFDA).

## III. Results

The optical subsystem of IA-FiMeSy captures the sharp fiber images for later analysis; the mechanical sub system supports and covers all other parts of the system; the electronic sub system allows to automate and control the scanning process. The AI-based software identify fibers according medullation, saves the results, allow to enter sample identification data and to view AFD histograms of fibers with and without medullation.

This new system identifies automatically NM, FM, UM, CM and SM fibers of alpaca, llama and mohair. Also measures AFD global and by medullation type. In addition, it obtains the number and percentages of NM, FM, UM, CM and SM fibers (Fig. 1). Each sample is evaluated in 40 sec, considering about 1500 fibers/sample.

At two-proportion z-test of different fiber medullation types obtained with direct counting and our system no significant differences were found (Table 1). Also, at t-test of AFD obtained with OFDA and IA-FiMeSy no significant difference were found either, but the relationship between these methods was very stronger (r=0.95).

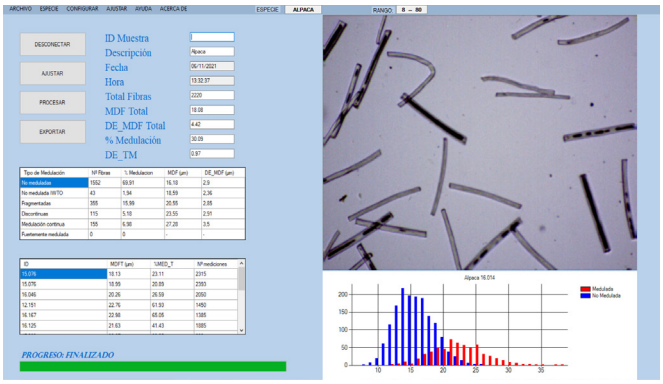


*Figure 1. Graphical user interface (GUI), showing the evaluation results of fiber sample.*

TABLE 1. TWO-PROPORTIONS Z-TEST RESULTS OF ALPACA, LLAMA AND MOHAIR FIBER SAMPLES ACCORDING TYPES MEDULLATION (*IN ITALIC: % WITH DIRECT COUNTING*; **IN BOLD**: % WITH IA-FIMESY; IN RED: P-VALUE)

| *Sample* | *NM* | *FM* | *UM* | *MC* | *SM* |
|---|---|---|---|---|---|
| **Alpaca: N= 2108** | *25.41* **26.06** 0.698 | *23.85* **24.05** 0.902 | *14.53* **13.89** 0.480 | *30.33* **31.59** 0.635 | *2.76* **1.72** 0.069 |
| **Llama: N= 1858** | *64.21* **63.38** 0.600 | *16.79* **16.99** 0.874 | 4.63 **4.58** 0.942 | *10.66* **11.31** 0.528 | *1.61* **1.27** 0.380 |
| **Mohair: N= 901** | *91.11* **89.99** 0.412 | *0.22* **0.54** 0.274 | *0.11* **0.43** 0.191 | 1.44 **0.75** 0.156 | *7.11* **8.29** 0.345 |

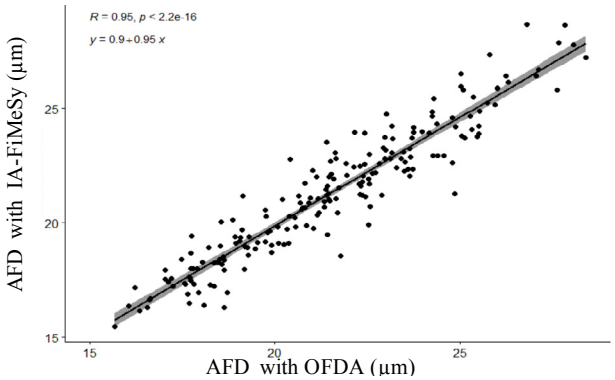


*Figure 2. Scatter plot of AFD obtained with OFDA and IA-FiMeSy. Correlation Pearson and regression equation is showed, also.*

## IV. DISCUSSION

The fragments and medulla of the alpaca, llama and mohair fibers have the peculiar characteristics, but IA-based software identify their types medullation based in thousands of equations, so that, it was convenient to develop a model for each type of fiber. Therefore, the developed system would have the potential to evaluate the medullation of other types of fiber, for which it will be necessary to develop a model based on AI.

The similarity of the results of medullation and AFD with other commercial device (PM, and OFDA), as well as the portability, practical, no expensive, use-easy, fast are advantage of IA-FiMeSy. Therefore, it can be used in practical way by researches, farmers, marketing and others stakeholders.

With this new system a genetic improvement program can be carried out, considering as a selection criterion % of CM and SM fibers, with whose reduction – through improvement genetic in alpaca, llama and mohair fleeces – the problems of prickling, quality fabric and processing performance of these fibers would be solved [4].

## V. CONCLUSION

The IA-FiMeSy is an equipment with four parts: Optical, electronical, mechanical and software, which interact to capture thousands of fibers image by means of scanning that are then processed through AI-based software to finally provide measurements of medullation and AFD. This device can be used for evaluation of alpaca, llama and mohair fibers because it has a good precision and accuracy. Additionally, fiber assessments between IA-FiMeSy with PM, PFT and OFDA have a high correlation and without significative differences. While the measurements are being carried out, the IA-FiMeSy shows sharp and defined images, allowing the user to view the images of the fibers on real time. For these considerations, the use of this new system is recommended for fiber evaluation for the purpose of genetic improvement of fibers in animal production; purchase-sale, and processing of fiber to verify the quality of fibers; and research on medullation to increase knowledge about alpaca, llama and mohair fibers.

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